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Fig. 1—Outdoor-type instrument transformers are used at this transformer bank. The current transformers are located at A whereas the position of the potential transformers is shown at B. The meter is installed in the building adjoining.

Departmental Metering Practice

In Industrial Plants

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POWER costs may or may not be a prime factor in determining the profits or sale price of a manufactured article, but in the majority of plants these costs are becoming more important as production is speeded up, with a corresponding reduction in man-hours per unit produced.

Power is a commodity the same as any other raw material entering into manufacturing processes and no relation between its consumption and department production can be established without departmental metering. Changes are constantly taking place in the condition of the equipment in each department; friction will vary or temperature conditions may alter the load on many machines so that, other things being constant, the power consumption reflects the changes in the condition of equipment, and indicates when and where an investigation or test is required. Furthermore, in a progressive, growing plant changes and alterations are constantly being made to both equipment and methods, and the question of whether power consumption has been increased or decreased frequently arises.

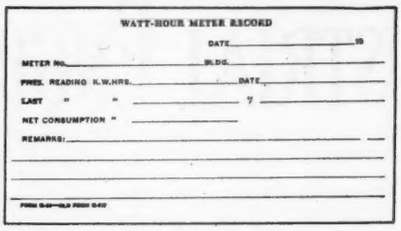
Metering the electric power delivered to the various departments of an industrial plant takes the pulse beat, so to speak, of each member of the plant family, so that each department may be placed on a sound footing, from the standpoint of operation, and encouraged to better endeavor. The results anticipated by a change in manufacturing methods or equipment may be weighed in the balance by the meter. In some cases increases in power consumption indicate a conservation of man-power, a liberation to direct larger activities; perhaps the relation of kilowatt-hours required to replace a man in one department or another may be the yardstick required to compare results.

Departments should be charged with the power used to prevent

waste of power, if for no other reason. Incentive is a great driving force if properly applied and when a definite billing is made against a department an incentive is given to that department to reduce its power bill. If it is a laboratory, the hot plates will be cut off when they are not required for an hour or so. If it is a shop, the various power tools will be shut down when not in use, or the drives may be regrouped to prevent running a 50-hp. lineshaft motor in order to operate a lone power hacksaw. Thus results in the way of saving power that could never be produced by direct orders will gradually be brought about by a careful check on power consumption. To say the least, power is expensive whether it is purchased or generated, as a by-product or in a hydro-electric plant. The capacity required to furnish the power is, in the last analysis, about as great in one case as another; and capacity plus operating charges means the interest on $100 to $200 for every kilowatt demanded at one time, plus a variable operating charge per kilowatt-hour. Cost acountancy must take account of all items of cost if anything is to be known regarding the cost of producing an article of commerce. For accuracy the power must be metered as a whole, subdivided into departmental units and metered again in order to pro-rate properly the departmental charges for the power consumed.

The mechanism for gathering the data concerning the power used by each department may be either simple or very complex, depending on the inter-relation of departments. In the design of a new plant or the revision of an old one the provisions for adequate and satisfactory metering may easily be made. The size of the plant and the amount of power used in each department determines the layout to be used. The logical place to install metering equipment, is of course, at the source and again at each of the load distribution centers. The latter may be in the substation or power house, in the small plant, or they may be at distant points in the larger plants. A choice must also be made between metering on the high-tension side or the low-tension side of the distribution transformer bank.

Where only one metering equipment is to be installed at the transformer bank for small blocks of


WATT-HOUR METER RECORD

DATE _____ 19

METER No. _____ BLDG. _____

PRES. READING K.W.HRS. _____ DATE _____

LAST " " _____ " _____

NET CONSUMPTION " _____

REMARKS: _____

Fig. 2—Watt-hour meter readings of power consumption are recorded on this card.

The location of the meter is recorded, with its serial number, the date read, and the dial readings. From the previous reading the net consumption is calculated.

power and for temporary installations, the outdoor, 2,200-volt installation is quite common. The equipment consists of two potential transformers and two current transformers, with a suitable meter. Suitable brackets are needed for attaching the transformer to crossarms, or other structures, and a metal box, well grounded should be supplied to house the watthour meter, which should be mounted near the ground on a pole, tower, or adjacent building, as the case may be. An installation of this type is shown in Fig. 1. In this instance the meter is located inside the building. Most of the trouble experienced with this type of installation can usually be traced to lightning.

With this method of metering, the transformer losses are measured and charged to the department as power consumed. It is the rule in many plants to segregate the total line losses and charge them into general plant accounts as they naturally fall into overhead expense. The line losses for the plant, obtained by subtracting the total energy consumed, as registered by the sum of the department meters, from the total energy registered by the master meter at the source, indicate whether any departmental meter or the master meter is out of order. Any great change in line loss, which is a rather uniform percentage of the total load, indicates incorrect registration of some meter. In one large plant, a blown potential fuse on a meter was detected by a change in the line losses and corrections were made to the incomplete meter reading that were within 5 per cent of the actual value, as the line losses were known for different operating periods.

Fig. 3—Switchboard type meter installation for registration of primary power.

This shows the potential test terminals to the right, and the current test terminals mounted directly above the meter on the face of the panel to facilitate routine testing.

At times one department, B, may be situated so that it is at the end of a distribution line to another department, A. In order to save the heavy expense of a duplicate feeder to serve a light load a meter is installed in department B. The meter for department A will then register the total power taken by both A and B, so in this case the power consumption is obtained by indirect reading, that is, subtracting the consumption of B from that of A to sesure the net consumption for the latter.

The monthly meter readings may be kept in a standard form of meter book, some of which provide space for the numerical dial reading, whereas others have a printed meter index for every reading so that lines drawn on the printed index indicate the exact position of the dial hands at the time of reading. For reporting the meter readings, the meter reading card shown in Fig. 2, is used.

Before developing a system of metering for a plant in operation, a comprehensive survey should be made of the connected loads. These should be grouped to include the natural departmental divisions, such as power house auxiliaries, plant water pumping, machine shop, and allied facilities, and process groupings. These are given as suggestions indicating some of the natural divisions. The proposed grouping must next be reconciled with the existing electrical plant wiring dia-

gram, which will be similar to that shown in a previous article on page 358 of the August, 1925, issue of INDUSTRIAL ENGINEER, by a rearrangement of circuits, if this is necessary.

If a motor test record is available covering the motor installations a study of the peak and average loads per group will be greatly simplified. Such a study will usually prove to be of much interest and value even if the proposed metering plan is later abandoned. For stabilized departments, such as the shop facilities and water pumping, the metering equipment may be considered as fairly permanent because no great change will be made except in the case of a complete enlargement of the entire plant. Very little excess capacity in the metering equipment would be necessary for such departments. In the process departments much greater latitude should be allowed and an excess of capacity ranging from 20 to 40 per cent may be provided, depending on the nature of the plant. Operations may be regrouped, expanded or otherwise altered as has been mentioned previously.

Within the range of circuit capacity, the current transformer ratios should be selected in evenly spaced groups so that in case the metering capacity is exceeded it is necessary only to transfer current transformers from one installation to another, should the loads increase progressively. It sometimes works out that a set of 600-amp. transformers are bought to replace those in a 400-amp. installation which may be used to relieve some 200-amp. transformers, and so on down the line, indicating that the general trend is toward increased power consumption in all departments of the modern industrial plant.

The typical plant circuit for distribution to motors is operated at 440 volts, three-phase, 60 cycles, and it follows that the typical metering equipment for that circuit will consist of two current transformers and a 5-amp., 440-volt meter with a self-contained potential circuit. Of course, meters with self-contained current circuits can be obtained up to 100-amp. capacity or more, but they are unwieldy to handle and a much larger investment is tied up when they are put on the shelf due to the ever increasing loads on the circuit.

As stated before, when selecting current transformers, care should be taken to see that the current ratios are evenly spaced, so that as the circuits become overloaded these transformers may be moved progressively from one circuit to another, as is often possible.

Individual circuits are in general limited by two factors: the economical size of conduit and the largest single body fuse which can be used. It happens that the two coincide and our practice has been to subdivide

METER TEST RECORD

MAKE _____ TYPE _____ SERIAL NO. _____

AMPS. _____ VOLTS _____ WATTHOUR CONSTANT _____

LOCATION BLDG. _____ DEPT. _____ RECORD NO. _____

DATE	REV. STANDARD METER	REV. SERVICE METER	PER CENT SLOW	PER CENT FAST	REMARKS

FORM Y-207-E.

Fig. 5—Here is a secondary meter test record card.
On this card the meter nameplate data and results of periodical tests are recorded.

Fig. 4—This is the primary meter test record card.
On the front of the card, the nameplate data of the meter and instrument transformers used are recorded, with a note on the condition of the meter when installed. On the back of the card the results of periodical tests are recorded for purposes of comparison.

MADE IN U. S. A.
421 1M-10-25

METER TEST RECORD

MFG. General Electric Co. SERIAL NO. 4868081

LOCATION No 3 Generator VOLTS 13200/110 AMPS. 150/5

WIRE 3 PHASE 3 TYPE DS-6 CYCLE 60

METER CONSTANT 1000 READING ✓ 0000

CONDITION OF METER

CASE OK DIAL OK SEAL None JEWEL OK

GEARS OK MAGNETS OK DISC OK CREEP No

CURRENT TRANSFORMERS			POTENTIAL TRANSFORMERS		
MFG. G.E. Co	TYPE —		MFG. G.E. Co	TYPE —	
SERIAL NO. —	RATIO 30/1		SERIAL NO. —	RATIO 120/1	
VOLTAMPERES 200	CYCLE 60		V. A. —	VOLTAGE —	

REMARKS Meter has a tendency to run slow. Bearings Were Oiled, magnets cleaned and re-adjusted 8-11-26

TESTER James L. Reed

TEST RECORD

DATE	LOAD			REV. STD. MTR.			REV. SER. MTR.			RATIO	ACCURACY	
	10%	50%	100%	10%	50%	100%	10%	50%	100%		% S.	% F.
1-20-26	✓	✓	5	✓	✓	9.20	✓	✓	9	97.8	2.2	✓
3-17-26	✓	✓	5	✓	✓	9.10	✓	✓	9	98.9	1.1	✓
9-20-26	✓	2	5	✓	893	893	✓	9	9	100.7	✓	0.7
11-11-26	✓	✓	5	✓	✓	8.85	✓	✓	9	101.9	✓	1.9

the circuits so that the maximum conductor is 500,000 circ.mil in a 3-in. conduit, controlled by a 600-amp. fused, inclosed and externally operated safety switch. In case the maximum-sized circuit takes care of one department the metering equipment is installed in this circuit. If two or more such circuits are required a bus-type transformer may be slipped over the busbar section ahead of the taps for the other circuits. Seldom will more than two departments of large size be fed from one distribution center. In such cases, the second department will be metered by the indirect method as outlined above.

Meters should be checked for accuracy at reasonably frequent intervals, and the accessories needed with the metering equipment include fuses for the potential circuit of the meter and current links for the current transformer circuit. It is well known that a very high voltage is set up in a current transformer carrying load when the secondary circuit is opened, making it dangerous to both the transformer and the person handling the circuit. In view of the necessity of proper testing of meters at regular intervals and the value of a quick and safe method of connecting the test meter in series with the current elements in the installations I have made, two test terminals are connected in the current transformer secondary circuits. Each terminal has two spare connecting nuts under which the leads for the current coils of the test meter are attached between the pair of terminals. In this way the test meter is put in series with the meter under test without opening the circuit when the bridges between the other two bottom nuts are removed. This arrangement of terminals is shown in Fig. 6.

The frequency of testing meters should be adapted to the conditions in the plant and a record should be made of each test that will show the condition of the meter before and after testing. Meters that are important factors in calculating departmental efficiencies may be tested once a month, but the average plant meter should show little variation between yearly tests. If any meters, however, show a considerable variation from test to test, the interval between tests should be decreased until the underlying cause has been ascertained and corrected by whatever means are necessary.

Two meter test record cards are shown in Figs. 4 and 5, and cover test data on primary and secondary meters. In the case of primary meters, the full nameplate data as well as the instrument transformer data are recorded on the front of the card. The back of the card is used for the record of tests made under different conditions of load and on various dates.

The testing equipment for the field will usually consist of a polyphase rotating standard watt-hour meter with variable voltage and current taps, and a load resistance or phantom load box for testing meters under artificial load. Polyphase meters, which are subjected to variable loads and used where high accuracy is desired at all loads, should be brought into the shop for testing and adjustment. A simple test table with a current source and the necessary switches may be fitted up from ordinary materials at hand, or a special test table may be purchased. However, the average plant will not require a great amount of expensive testing equipment if a standard-type, 5-amp. meter can be used for all installations as is frequently the case.

The wiring diagram in Fig. 6 shows the connections for testing a Type OA, 5-amp., 440-volt, three-phase, three-wire Westinghouse service meter with a Westinghouse polyphase portable rotating standard test meter. The current leads are attached to the rotating standard meter and then inserted in the double test terminals. The removable links may then be opened by unscrewing a floating nut which places the current coils of the standard meter in series with the service meter without opening the current transformer circuit. The wiring may be run on the

(Please turn to page 204)

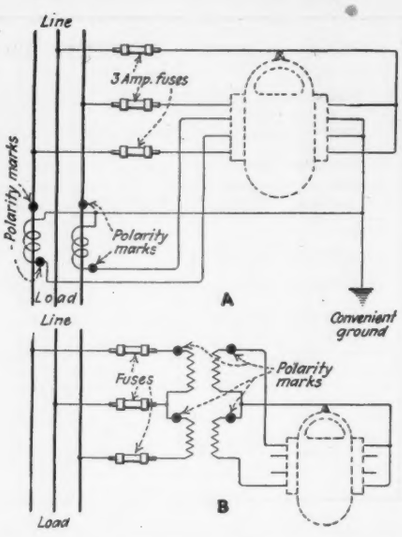
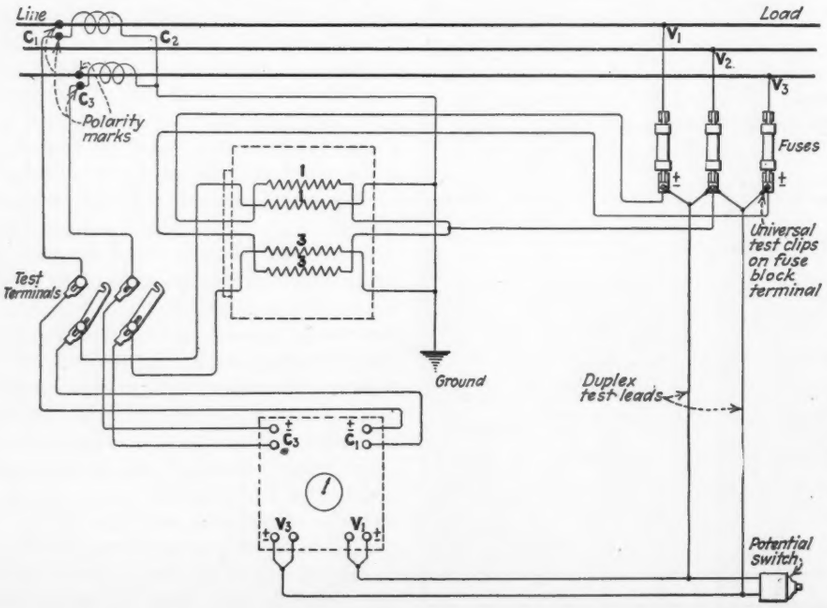


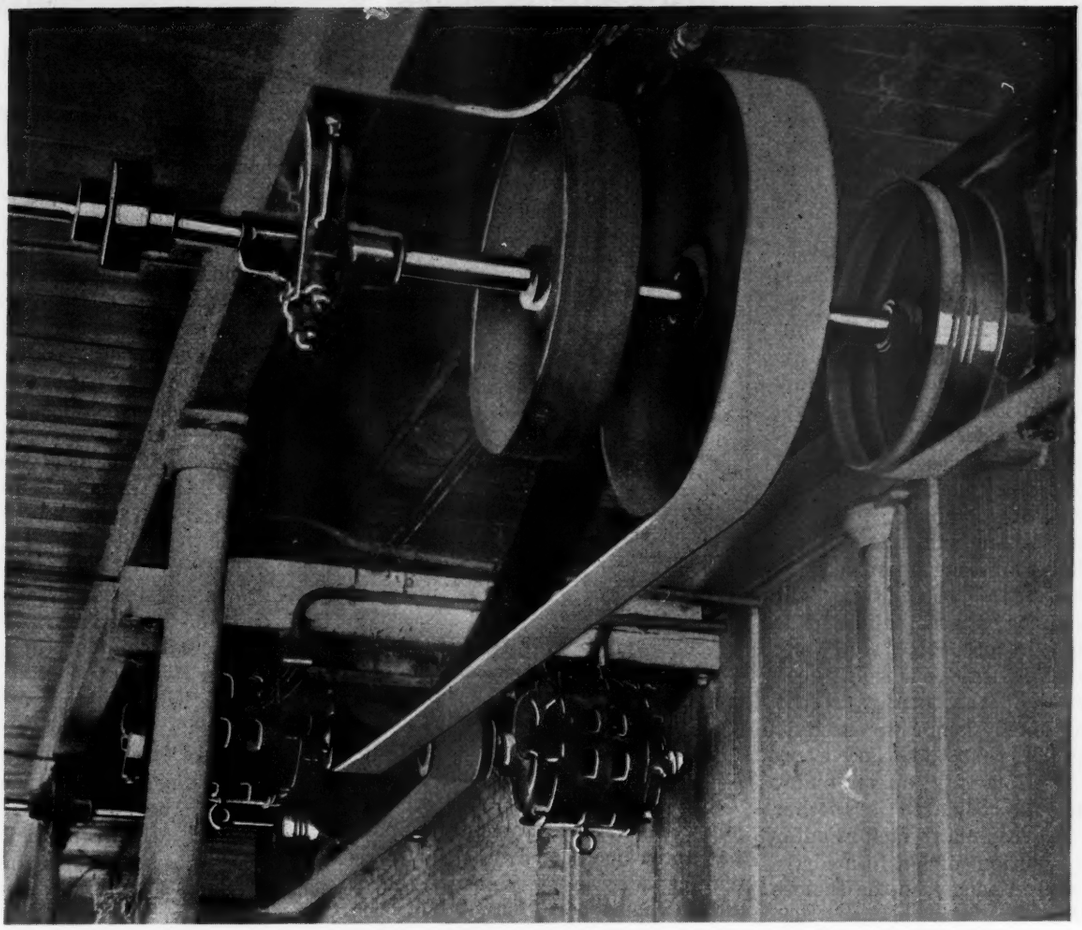
Fig. 7—Connection diagram for three-phase, three-wire meters employing instrument transformers.

The connections in *A* show the use of current transformers and the direct application of line potential through fuses in each phase. In *B*, connections are shown for using potential transformers for medium or high voltages. If required, current transformers would be connected as shown in *A*.

Fig. 6—Connection diagram for service meter test using rotating standard watt-hour meter.

This diagram shows the connections of a Westinghouse portable, rotating standard meter when used to check a Type OA Westinghouse meter taking service from a 440-volt source and using current transformers. The current coils of the rotating standard are cut into the service meter current circuits by means of the test links, without danger of breaking the circuit.





These 8-in. double leather belts operating on 14-ft., 10½-in. centers have been in 24-hr. service since 1905 in the woolen mills of the Wonalancet Co. The diameter of the motor pulleys, turning at 1,170 r.p.m., is 9 in., whereas the shaft pulleys are 37 in. in diameter.

Factors in determining

Proper Center Distances for Leather Belt Drives

By ROY C. MOORE
Chief Engineer,
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TRANSMISSION of power by leather belts is one of the oldest and most common methods used by industry. As with numerous other familiar industrial problems, there are many practices and rules-of-thumb associated with the selection of a belt for a particular application which, as long as they contain a sufficient factor of safety or ample rating, give satisfactory and reliable operation. For all belt work rules can be used only as a basis, because a large proportion of belt installations are not under ideal operating conditions, and so require some modifications to meet the particular situations.

The object of this series of articles, of which this is the first, is not to present a theory of the transmission of power by belting, but to outline conclusions regarding certain factors that will affect satisfactory operation of belts. These conclusions are not based on the results of experiments, but are drawn from experience with, and records of, belts in operation over a long period.

Many of the results given here will, therefore, appear conservative as compared with results of tests, but please remember that the elements of final cost and satisfactory operation have been taken into consideration in outlining the limiting factors. Tests are practically always made under laboratory conditions, while those under which a belt operates are often far from ideal. Also, a test covers a comparatively short portion of the anticipated life of the belt and the real life, even under the test conditions, can only be surmised.

Many of the remarks that follow will be statements of what to avoid doing, in the interest of final cost

and satisfactory operation, rather than what to do. Some of the statements may appear to conflict with good practice, but it must be remembered that where operating conditions are not ideal it would often cost too much to rectify them. When an operating man knows what makes good or bad operating conditions, he can often arrange a new drive so as to eliminate many of the improper conditions. Sometimes this is impossible and, therefore, many drives must be installed to operate satisfactorily under existing conditions. It is for these exceptional drives that the following data will prove of greatest value.

This first article will take up some of the important considerations in connection with determining the proper distance between pulleys. The answer to the question, "How long should a man's legs be?" holds good in every case; the answer, "They should be long enough to reach to the ground," seems to satisfy every condition. How far apart pulley centers should be placed is another matter. A great many factors enter into the solution of such a drive problem and in each case the factors differ; therefore, the solutions also vary.

Inasmuch as it is necessary to maintain an overload capacity for satisfactory service, any condition that will decrease this capacity must be carefully considered. It is evident that with a belt driving from a small to a very large pulley, with a comparatively short center distance, there is only a small amount of belt in contact with the smaller pulley. It is reasonable to suppose that under such conditions the maximum capacity of the belt is lowered, and such has been found to be the case.

In all belt drives it is safer from both operating and cost standpoints to be conservative. For example, it is always well to use a moderate center distance, whenever possible. This gives rise to the question, "What is a moderate center distance?" It is readily understood, of course, that what may be a moderate center on one drive may be too short or too long on another drive, depending upon operating conditions. Some of these conditions will be pointed out in this article and illustrated by examples rather than by an attempt to define a moderate center distance, which is only relative and is affected by the circumstances surrounding the installation in any given case.

Pulleys that are slightly out-of-round, for instance, which is often true of improperly installed split pulleys, place an uneven strain on the belt that cannot easily be absorbed unless there is a suitable distance between the pulley centers. In other words, the uneven strain on the belt which is caused by the pulley being out-of-round must be distributed over a fair amount of the belt's length, if the strain is to be properly absorbed and not transmitted on to the next shaft, in a form of a shock load.

Where moderate centers are used the weight of the slack strand of the belt is sufficient to maintain a suitable tension without calling upon much of the belt's elasticity. Where short centers are used, however, the total pressure of the belt on the pulley is maintained largely through the elasticity of the belt. When it is necessary to call upon the elastic properties of a belt to maintain perfect tension, a certain amount of stretch is inevitable and the tension necessary to transmit the load soon falls below the point where it is satisfactory.

The elasticity of the leather in the belt is the physical characteristic of the material that permits it to give or stretch sufficiently to accommodate increased load, or shock load, and again regain its normal condi-

Table I—Arc of Contact on the Smaller Pulley

R	Arc of Contact in Deg.	Correction Factor
0	180	1.00
1	175	0.97
2	170	0.95
3	165	0.92
4	160	0.90
5	155	0.87

Table II—Center Distances Found Satisfactory in Practice

Type of Drive	Belt Width in Inches	Distance Between Centers in Feet
Countershaft Drives:		
Small....	2–6	Approx. 10–12
Medium.	6–10	Approx. 14–18
Large..	10 and up	Approx. 18–25
Main drives	12 and up	Not over 35

Fig. 2—Examples of belts operating with long center distances under three different conditions.
With the long center distance a comparatively slight stretch resulting in 1 per cent elongation gives enough sag for the slack side of the belt to almost touch the tight or driving side. Shortening the center distance or putting the slack side on the bottom overcomes this difficulty.

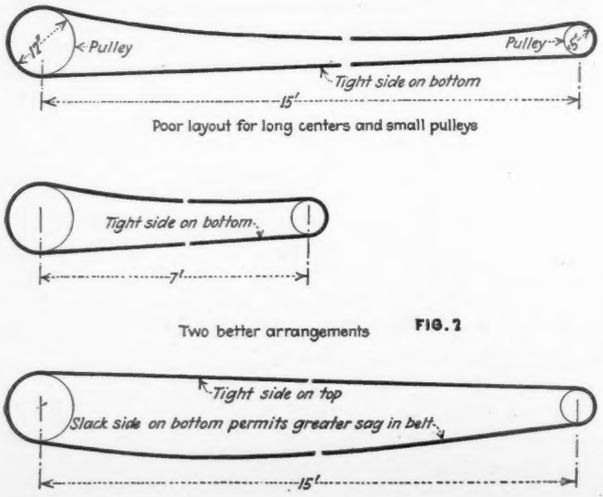
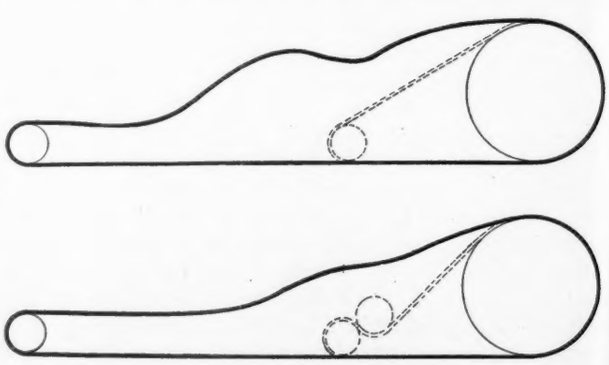


Fig. 3—Irregular loads cause a strong, wavelike motion in drives with long centers.
With such drives a shorter center distance is more suitable and the addition of an idler will make the drive operate more smoothly.



tion when the increase in the load is removed. However, when the load is greater than the elastic limit of the belt it does not return to its original length; in other words, the belt will have a permanent stretch. Excessively high tension, such as would be necessary on very short centers or when the belt is overloaded, results in excessive stretch, which not only necessitates more frequent maintenance, but also shortens the life of the belt.

From past experience in laying out large compressor drives, and drives with a large difference in diameter between the two pulleys, it has been found that the arc of contact on the smaller pulley should never be less than 155 deg. For good practice it has been found that an arc of contact of less than 165 deg. necessitates running the belt at high tension.

A simple rule that I have used to determine the necessary center distance to give a certain arc of contact on the smaller pulley is as follows: Divide the difference in diameter (in inches) of the two pulleys by the ratio R (Table I) to obtain the center distance in feet. This can be expressed in a formula: $(D - d)$ in inches $\div R =$ C.D. (center distance) in feet. $R =$ difference in diameter of pulleys in inches $\div$ center distance in feet. In case the quotient should come out as a decimal assume the closest unit value for R as given in Table I, and the second column of this table will give the corresponding arc of contact for that installation. As stated, it is highly desirable to get an arc of contact of at least 165 deg., and so values of R which will give at least 165 deg. of contact should be assumed and substituted in the formula until a satisfactory distance is obtained.

Table I gives the arc of contact on the smaller pulley corresponding to the value R obtained by the above formula, and correction factors (third column), that indicate the loss in the power transmitting ability of the drive, compared to a normal drive, because of the decrease in the arc of contact. For example, a drive with a 170-deg. arc of contact will transmit only 95 per cent of the rated belt capacity that would be transmitted if it were operated with a 180-deg. arc of contact. The loss increases rapidly with the decrease in the arc of contact, as may be seen from this table.

Where an excessive center distance would be required to give the desired arc of contact, a short-center drive with a flexible or gravity idler should be used. The application of the short-center drive will be discussed in a later article of this series and so will not be covered further here.

Table II gives a list of center distances that have been found satisfactory in practice. These apply more particularly to countershaft and mainshaft drives. When it is not possible to obtain the proper arc of contact it is always practicable to increase the width of the belt (providing the pulleys will permit it), or a heavier belt can be used. Either of these methods will compensate for the loss in ability to transmit power.

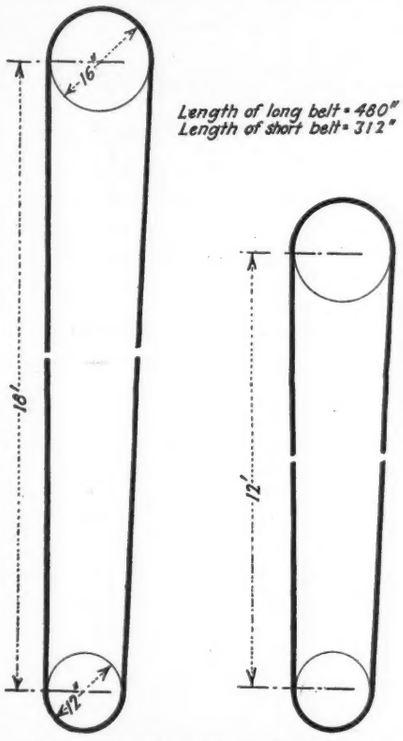


Fig. 4—Trouble with vertical drives increases with longer center distances.

On these two drives a total stretch of 5 per cent would mean an elongation of 24 in. in the belt at the left and 15 in. in the belt at the right. If the belt is shortened but 3 in. at a time the long-center drive would require cutting eight times against five for the shorter drive, or an increase of 60 per cent in the necessary maintenance.

The effect of misalignment of the pulley is not so readily noticed in drives with moderate centers as in the case of drives with short centers. When using longer centers the crown of the pulley has a better opportunity to correct misalignment in the drive. This, however, should not be accepted as an excuse for permitting pulleys to be out of alignment.

Drives with moderate or long centers are always objectionable where the pulley diameters are extremely small or where they operate in a horizontal position with the slack side of the belt on top. This condition often applies to belts driving a blower or fan. Fig. 2 illustrates what happens when comparatively small pulleys are placed on long center distances with the tight side of the belt below. It is interesting to note that a sag of 4 in. in the slack side of the belt represents an elongation or stretch of only 3.8 in. or approximately 1 per cent of the total belt length. With a sag of slightly over 5 in. (the diameter of the smaller pulley) the slack side of the belt would rub on the tight side and necessitate shortening. This would have to be repeated each time the belt elongated under load a little over 1 per cent of its length.

The two lower sketches in Fig. 2 show better arrangements. Shortening the center distance to approximately half, if this is possible, gives a most satisfactory arrangement. In this case a sag of 4 in. in the top or loose strand of the belt represents 8.3 in. elongation, or approximately 4 per cent of the belt length. The belt could, therefore, run considerably longer before it would be necessary to cut and shorten it.

When it is not possible to change the center distance, but the drive can be changed to put the slack side on the bottom, as is done in the lower sketch of the three in Fig. 2, the amount of stretch or sag in the belt does not interfere with the operation of the drive. In fact, the weight of the long belt assists in maintaining adhesion to the pulley surfaces.

For high-speed belts, where the load is variable, shorter centers are more suitable than long centers. With the short centers the flapping of the loose strand of the belt, which may result from any unevenness of the load, is markedly decreased. This is well illustrated in Fig. 3. The belts shown in solid lines indicate the decrease in the wave which results from shortening the center distance. Very short center distances, as in the belt installation shown dotted in the upper sketch of Fig. 3, practically eliminate the slack and consequent waves but decrease the arc of contact and require higher belt tensions. These objections may be overcome by the use of gravity idlers, as shown by the dotted lines in the lower sketch of Fig. 3.

In the case of a hot-saw belt, or an edger drive, the load goes off quickly as the saw cuts through the material and these belts often ride back and forth across the pulley face before they have an opportunity to contract and center themselves again. This condition is more pronounced with long center distances. Where the load is steady a belt may operate up to 5,000 f.p.m. with any reasonable center distance without giving much trouble. It is on those drives where the speed is excessive and the load variable that serious operating troubles are encountered.

This discussion, so far, has covered only horizontal belt drives. Practically the same considerations, however, apply to inclined drives where the angle of inclination is not over 45 deg. Also, as the angle of the belt approaches the vertical the operating difficulties increase, because as it stretches the belt tends to hang away from the lower pulley. This operating condition will be discussed in more detail in another article of this series.

A vertical drive laid out with long centers invariably causes trouble because of the necessity of frequent take-ups. A short center cuts down the percentage of stretch in the belt in proportion to the decrease in the length of the belt. The number of take-ups, therefore, are much less frequent for the short-center drive. This is well illustrated in Fig. 4. In this case the drive at the left has a center distance 1½ times as long as the shorter drive at the right. The comparative belt lengths are 480 in. and 312 in. respectively. A total stretch of 5 per cent over a long period of service would mean an elongation of 24 in. in the longer belt and 15.6 in. in the shorter one.

With vertical drives the belt must be shortened frequently to maintain the proper tension and adhesion on the lower pulley. Assuming that 3 in. are cut out at each shortening, the long belt will require eight cuttings against five for the shorter belt, or 60 per cent more servicing; therefore, some allowance must be made for the long centers when comparing the amount of stretch and servicing of two vertical belts.

When it is necessary to use long centers on vertical drives, it is always advisable to allow ample width in the belt, which permits decreasing the necessary tension and so results in less stretch. This, in turn, permits the belt to operate longer before it is necessary to shorten it. The diameter of the pulleys also affects the power transmitting capacity of the belt under these conditions, but the discussion of this factor is also reserved for a later article. The use and proper positioning of flexible and fixed idlers will be discussed in the next article of this series, to appear in an early issue.

Departmental Metering Practice

(*Continued from page 200*)

rear of a panel and be attached by studs to the test terminals and fuses mounted on the face of the panel, or potential studs and binding post may be mounted on the face of the panel with the fuses on the rear.

The insulated spring jaws of universal battery test clips on the ends of the potential test leads grip the fuse terminals and make a good connection without loosening any parts. Assuming that normal load exists at the time and that the power factor of the load is above 50 per cent, the rotating standard should be tested for correct rotation on each element of the service meter by alternately disconnecting a potential lead from each element. Disconnect the lower $\pm$ lead on one side and replace it after noting the direction of rotation; then disconnect the lower $\pm$ lead on the other side for a similar observation. If the rotation is correct on both elements, proceed with the test; if it is not correct, reverse the current lead on the side showing reversed rotation, being careful, however, to close the test link so as to bypass the standard meter.

In testing the service meter, the revolutions made by its disk in a period of about one minute are counted and compared with the number made by the rotating standard. For this purpose the large pointer of the rotating standard should be set at zero and the reading of the smaller dial recorded. Snap the potential switch when the black mark on the service meter disk passes the glass window in the case, or some fixed point if the case is removed, and again snap the potential switch when the disk passes the window or its fixed point after making the desired number of revolutions. From the data recorded, the accuracy of the service meter in per cent can be determined by the following formula:

$$\text{Accuracy of meter} = [(R_s \times K_s) \div (R_w \times K_w)] \times 100$$

where

K_s = Watthour constant of service meter.

R_s = Revolutions of service meter.

R_w = Revolutions of portable standard meter.

K_w = Watthour constant of portable standard meter.

For example, in Fig. 4 the meter test record card for No. 3 generator, date line 1-20-'26, indicates that the service meter while under test made 9 revolutions to 9.20 revolutions made by the standard. This General Electric service meter has a watthour constant of $\frac{2}{3}$ and the Westinghouse standard used has the same constant; therefore, according to the formula the accuracy of the meter is, $(9.0 \div 9.20) \times 100 = 97.8$ per cent. In other words, the service meter was found to be 2.2 per cent slow. When necessary, it is customary to adjust the magnets of both elements an equal amount, if possible, and leave the meter as nearly correct as it can be made. The meter is called correct if its accuracy is found to be within 0.5 per cent on five repeated checks after adjustment. In case the service meter constant is different from the constant of the standard, its correct value may be secured from tables provided by the manufacturer.

The calculation of meter constants seems to puzzle many of us, although it is simple enough after all. If a 5-amp. meter is connected in the secondary circuit of 500/5-amp. current transformers, the transformer ratio is 100:1. Simply multiply the meter constant on the dial by 100, to obtain the new meter constant which must be used for the correct registration of power consumed. When potential transformers are used in connection with current transformers the new constant will be the product of the transformer ratios and the dial constant. Fig. 7 shows the method of connection when it is necessary to use instrument transformers.

The training of metermen has been given careful attention by the National Electric Light Association and different manufacturers, and many state universities and other schools have co-operated and established short courses covering this subject. Several excellent books have been published covering meter testing, in addition to a number of handbooks and bulletins that have been put out on this subject.

Functions of Control

in the Operation of Electric Motors

By H. D. JAMES

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IN THE previous article of this series, which appeared in the March issue, it was pointed out that the controller is an essential part of every drive that uses an electric motor to convert electrical energy into mechanical work. The controller regulates the power applied to the motor; it also modifies the characteristics of the motor so that the rotation is in the proper direction and the necessary speed adjustment is obtained.

In brief, the controller is to the motor what the valve gear and the throttle are to the steam engine, but the controller is more flexible and has a wider range of application than the valve gear, as it controls both the acceleration and the retardation of the motor. The speed of a steam engine depends upon the load, and its performance is somewhat similar to that of the series direct-current motor, but we have no analogy between the adjustable-speed motor and any engine.

Function of Control in Starting an Electric Motor

Electric power is usually delivered to the user at a constant potential and frequency. The direct-current motor is sensitive to the voltage applied to its terminals, as this must not exceed the counter-emf. by more than a few volts. In starting such a motor it is, therefore, necessary to reduce the voltage applied to the terminals of the motor by means of a controller. The customary method of reducing the voltage is to pass the current through a resistor which converts most of the electrical energy into heat, leaving only a relatively small voltage at the motor terminals to produce the torque necessary to start the load. As the motor accelerates, it generates a counter-emf. so that the voltage at its terminals must be gradually increased by reducing the resistance in series with the motor. When full speed is reached, all of the resistance is eliminated.

A manual controller may be used and the rate of short-circuiting the resistor left entirely to the judgment of the operator. This may be desirable as most motors can withstand overloads for short periods of time; therefore, a too-rapid short-circuiting of the resistor usually causes no harm although it may place an undesirable strain on the equipment. The most common forms of manual control are the faceplate starter and the drum controller.

Where magnet contactors are used and controlled by a master switch, the short-circuiting of the starting resistor can be made automatic. This means of acceleration is usually provided with magnetic control so that the only function of the operator is to initiate starting. Where speed control is one of the functions, the push-button station is usually replaced by a master switch having several positions corresponding to the speeds required. There are three common methods of acceleration: namely, time delay, counter-emf., and current limit. Sometimes a combination of these is used.

The alternating-current motor is not so sensitive as the direct-current motor to the voltage applied at the time of starting. The smaller sizes of squirrel-cage motors are frequently started by connecting to full voltage. The wound-secondary induction motor has external resistance connected in the rotor circuit during the starting period. These latter motors perform very similar to a direct-current series motor, torque being in proportion to the current.

The direct-current motor can be converted into a generator to assist in retarding the load. The usual method of accomplishing this is to connect the brushes of the motor through a resistor, and is known as "dynamic braking." A dynamic braking controller, with the connection diagram, is shown in Figs. 1 and 2. If the motor is shunt wound, the field must remain excited; if self-excitation is used, the braking effect decreases very rapidly with the speed. Series motors must have their field windings reversed.

THIS is the second article of a series in which Mr. James is discussing the functions of control equipment in the operation of electric motors, and describing the construction and operating principles of the types of such equipment in industrial use. The first article appeared in the March issue and dealt with the general application of control equipment. The third article of this series will appear in an early issue.

How Control Functions in Stopping a Motor

Dynamic braking may be obtained by providing the reverse switches with back contacts, so that when both switches are opened, they complete the circuit through the braking resistor. Sometimes it is desirable to short-circuit portions of this resistor during slowdown, but this is not ordinarily required as the friction load is sufficient to stop the motor after the speed is reduced.

Another form of braking is obtained by increasing the internal or counter-emf. of the motor, so that it is above the line voltage. This causes the motor to operate as a generator, returning power to the line, and is known as "regeneration." Shunt motors having an adjustable field strength will very readily regenerate when changing from a higher to a lower speed. This regeneration may be so violent as to cause damage if it is not regulated.

The writer recalls several instances in which shunt motors were connected to overhauling loads. In lowering a load, the motor was driven considerably above its nor-

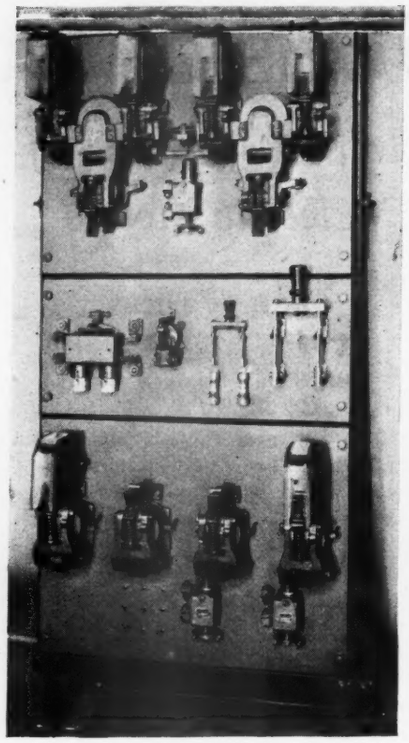


Fig. 1—This controller stops the motor by the application of dynamic braking.

The connections for this controller are shown in Fig. 2. On the top panel are the forward and reverse magnet contactors, marked *1* and *2*, *3* and *4*, respectively, in Fig. 2. These contactors are mechanically interlocked and operate the current-limit relay which controls the closing of the first accelerating switch. When both reversing contactors are opened the dynamic braking circuit is completed through the bottom contacts (*1A* and *4A* in Fig. 2) which are held closed by the bottom coils until the motor is brought to rest. These coils are either in series with the dynamic braking circuit, as shown in Fig. 2, or shunt coils may be used and connected across the motor terminals. On the bottom panel at the left is the line contactor shown as *5* in Fig. 2. On the right-hand side of this panel is the first accelerating contactor, *11*. The current-limit relay under this contactor controls the adjacent accelerating contactor, *12*. Its relay in turn controls the last accelerating contactor, *13*. On the center panel are located the main line knife switch, control circuit switch and fuses, low-voltage relay, and two-pole overload relay.

mal speed with a weak field; then the field was abruptly increased to its maximum value. A 500-volt motor operated in this way developed over 1,500 volts across the brushes which resulted in flashing and insulation troubles. Series motors operating cranes sometimes have a severe dynamic braking applied by the limit stop. If the motor enters this limit stop, running light, it may generate an abnormal voltage when the dynamic brake is applied.

Regeneration with series motors is used for railway applications and presents many interesting problems. The motors are usually grouped in series-parallel combinations, which give considerable flexibility for regenerative connections.

If a direct-current shunt motor or an alternating-current induction motor is operating at full speed and the line voltage is abruptly decreased, the motor regenerates and reverses its torque. This drop in voltage may be caused by starting another motor, or the dip may be the result of a line disturbance. The reversal of torque is sometimes objectionable, particularly if the motor is connected to the load by means of a chain, as this type of drive has considerable lost motion. Gear drives "knock" at such times, due to the lost motion of the gearing and some of the gear teeth may be broken. If the motor is belted to the load the reversal of torque may throw the belt off the pulley. The effect of the voltage drop depends very much on its magnitude and the abruptness of the drop.

Alternating-current induction motors wound for different pole combinations regenerate when the combination is changed to give a lower speed, as the motor then operates above synchronism during the retarding period. This type of motor should be applied to the load with care or else the controller so arranged that the motor circuit remains open until the speed has been reduced to the normal value for the pole combination used. Some applications do not require operation at reduced speed until after the machine has been stopped. Direct-current motors operating from two or more voltages regenerate when changed to a lower voltage, so that the controller must provide current-limiting means during the transition period.

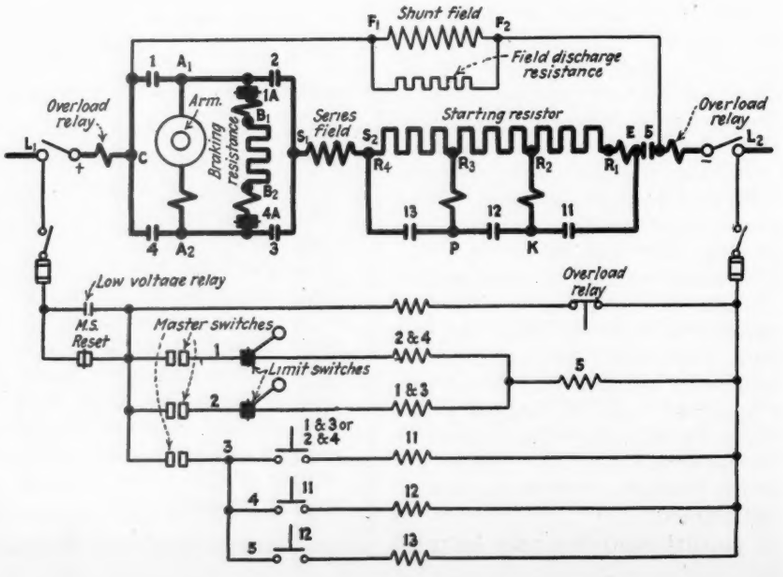
A friction brake is often used to assist in stopping the load and is particularly desirable in cases where the load will overhaul, as on hoists. Here the brake not only assists in stopping the load, but also holds it in a fixed position until power is applied to the motor. The friction brake is usually applied by springs and released by a magnet and is, therefore, commonly called a magnet brake. On large mine hoists oil or air pressure is used for applying the friction brake, in order to make possible easy adjustment of the friction load.

When magnet brakes are used with direct-current motors, the magnets are usually connected in series with the motor armature, although some applications require a shunt brake. Alternating-current magnet brakes are always shunt wound, as the impedance of the brake circuit prevents it being used in series with the motor.

Reversing the Direction of Rotation

When a motor is started from rest, the normal voltage is impressed on the starting resistance. If, however, the motor is operating at full speed and the armature connections are reversed, the counter-emf. is added to the line voltage, so that more resistance is required to limit the current to the same value as when starting from rest. It is usually assumed that the total volt-

Fig. 2—Diagram of connections for dynamic braking controller shown in Fig. 1.



age at such a time is approximately double the line voltage.

Controllers that permit the motor to be reversed at full speed are called plugging controllers. A controller of this type is shown in Figs. 3 and 4. One section of resistance is provided, which is automatically short-circuited at once when the motor is started from rest. If, however, the motor is running this section of resistance is kept in circuit automatically until the armature is approximately at zero speed. This section of resistance is usually known as plugging resistance, and has an ohmic value approximately equal to the starting resistance. Control of this type is commonly used on the table rolls in steel mills, but may be used for any application which requires this type of control. Some reversing planer control is of the plugging type.

If dynamic braking is used for stopping the motor, the coils of the dynamic braking contactors are usually connected in the circuit so that their contacts remain closed until the motor is at zero speed. This automatically prevents the reverse switches from being closed while the motor is still generating counter-emf., and prevents the motor from being plugged.

Control of this type is very common, not only in steel mills, but for reversing planers, elevators, hoists and other applications. Many engineers believe that it is easier on the equipment and, therefore, preferable to the plugging control where the rapidity of operation will permit its use.

Plugging control is required where the motor is started very rapidly

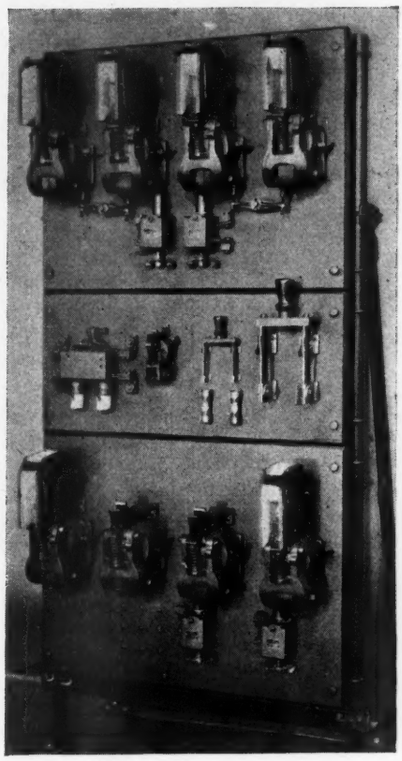


Fig. 3—This is a plugging controller used when rapid reversal of a motor is necessary.

The connections for this controller are shown in Fig. 4. The four contactors at the top of the board (*1, 2, 3,* and *4,* in Fig. 4) make the reversing connections; two contactors are closed for each direction of rotation. Current-limit relays are shown underneath two of the contactors. These relays control the first accelerating contactor, *11* in Fig. 4. On the bottom panel are four contactors. The one at the left is a line switch, shown as *5* in Fig. 4. The contactor at the right, *11*, short-circuits the plugging resistance. The relay under this contactor controls the next accelerating contactor, *12*. The relay under contactor *12* controls contactor *13*, which completes the acceleration. On the center panel are the main line knife switch, the control circuit knife switch and fuses, the low-voltage relay, and the two-pole overload relay.

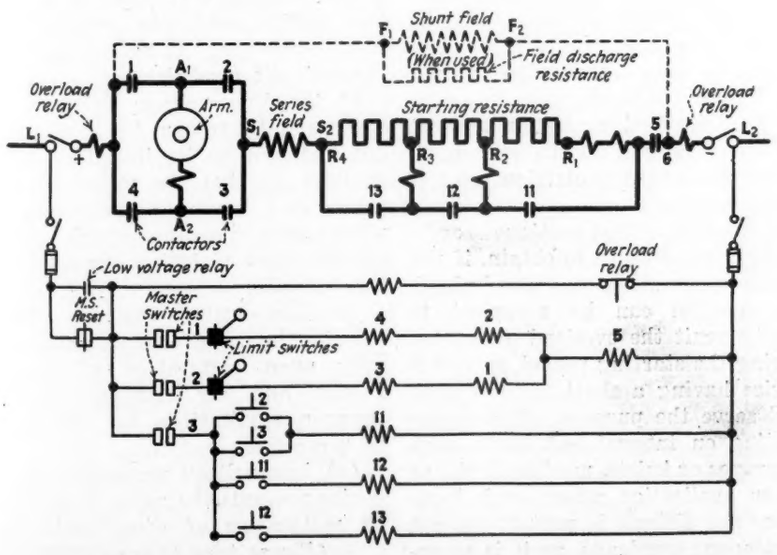


Fig. 4—Diagram of connections for plugging controller shown in Fig. 3.

either in the same or in the reverse direction.

The plugging of a motor using manual control, causes severe arcing on the controller, and usually is not necessary for proper handling of the machine. Manual controllers do not provide automatic means for retarding the short-circuiting of the control resistor and, therefore, careless handling often places abnormal strains on the equipment. These controllers may be protected by a contactor and instantaneous overload device, which will disconnect the motor from the line when the controller is improperly handled.

Adjusting the Speed of the Motor

Many applications require the motor to operate at different speeds. There are two general types of speed control: one having a speed which varies with the load; the other a definite speed independent of the load.

If a direct-current, series-wound motor has resistance connected in the armature circuit, the speed of the motor will depend upon the amount of resistance in circuit and also upon the load. The performance is very similar to that of a steam engine, the controller taking the place of the throttle valve. The speed of the steam engine will depend upon the load and the opening of the throttle valve, if the governor is disconnected. If it is desired to hold the engine speed at a fixed value, a centrifugal governor is used to regulate the amount of steam delivered to the engine.

A centrifugal governor could be provided for the series motor to regulate the amount of resistance in the circuit so as to maintain the speed at a constant value independent of the load, but this is not necessary as the shunt-wound direct current motor is used where constant speed is required. The wound secondary induction motor with resistances in the secondary circuit controls in a similar manner to the direct-current series motor, the controller being used for changing the resistance, to change the speed.

The direct-current shunt motor can have its speed adjusted by changing the strength of the shunt field. The control of this motor is similar to a mechanical drive con-

sisting of two cone pulleys connected by a belt. The speed at which the load is driven is changed by shifting the belt. This speed remains constant, independent of the load, providing the power driving one pulley maintains a constant speed.

The shunt motor runs at a constant speed, independent of the load, providing the line voltage remains constant. There is a slight change in speed with a change in temperature and also with a change in load, but this variation is small and is very similar to the belt slippage that would occur on the cone pulley drive, due to a change in load. For practical purposes, it can be assumed that the speed of a shunt motor remains constant.

The speed of a direct-current shunt motor is sometimes changed by connecting it to an individual generator and varying the field excitation of the generator. This method of control is called the Variable-Voltage System. It is used quite extensively for high-speed elevators and large reversing motors in steel mills.

The polyphase induction motor operates at a constant speed depending upon the number of poles. Some motors are arranged so that the number of poles can be changed by reconnecting the windings. This change in speed is the same as changing the gear ratio on an automobile. The most common arrangement is a 2:1 speed ratio which can be obtained with a single winding by reconnecting this winding for a different number of poles. If some other speed ratio is required, it is necessary to provide two separate windings.

Some motors are arranged to operate at four different speeds. They are provided with two separate windings, and each winding is arranged so that it can be reconnected for a 2:1 speed ratio. These motors are usually provided with a squirrel-cage rotor. If they have a wound rotor, it is necessary to change the winding of the latter in a manner similar to the change in the primary or stator. Motors of this latter type are used to drive the draft fans for steam boilers.

The speed of a polyphase induction motor can also be changed by changing the frequency. In some applications where a low starting speed is necessary, a small generator is furnished to give a low frequency for operating the motors when starting. Experimental installations have been made, using a separate machine for varying the frequency to obtain different motor speeds, but such systems have not found practical applications, as the Variable-Voltage System of controlling direct-current motors is simpler and no more expensive.

Provision for Sequence of Operation

In the first article, a number of examples were given of interlocking motor control to obtain the desired sequence of operation. The interlocking of control circuits is a very common feature in control systems and its application is more or less obvious. Thus, the doors on an electric elevator are interlocked with the control circuit so that the elevator cannot be started until the hatchway door and car gate have been closed. This is an interlocking device for the protection of persons. Again, a manual controller provided with circuit breaker protection may be so interlocked that the circuit breaker cannot be closed except when the controller is in its initial position. An interlock of this kind is for the purpose of protecting the equipment against abnormal starting conditions. Many illustrations of interlocking could be given, but its function is so easily understood that further examples are not necessary.

Necessity for Overload Protection

All controllers should provide some form of overload protection, not only to protect the electrical machinery from burning out, but also to protect the devices which are driven by the motor from mechanical injury. Overload devices may be divided into three groups:

(*1*) To afford protection against continuous overload.

(*2*) To afford protection against abnormal loads of short duration.

(*3*) To afford protection against short-circuits.

Protection against continuous overloads is not difficult to obtain, if the motor is operating on a steady load. The control can be arranged to short-circuit the overload protection during the starting period, so that a device having a short time element will serve the purpose. Motors operating on intermittent loads, such as cranes or hoists, machine tools, or other application where such loads occur are difficult to protect against continuous overloads, as it is necessary to provide an overload device that will not respond to the momentary overloads, but will disconnect the equipment when the load has overheated any part of the equipment, due to an unusually rapid cycle of operation, or to other causes.

Overload relays of the thermal type have been developed for this purpose, but so far the commercial relays provide this protection only for a steady heating of the electrical equipment, and other devices must be used to provide protection against short-circuits. Many of the dashpot-type relays and some other types have a sufficient short-time element to afford protection against abnormal overloads, and will operate before the fuse is melted. The amount of overload which the controller will handle is, of course, limited, depending upon the size of the controller, but in practice, it has been found that it will take care of abnormal loads that are not sufficient to melt the fuse protecting the feeder.

A fuse is the means that is usually relied upon to afford short-circuit protection. The Code requires all circuits and feeders to be protected (usually with fuses) so that the fuse back of the controller affords circuit protection to the electrical equipment, and prevents this equipment being destroyed by the ordinary short-circuit.

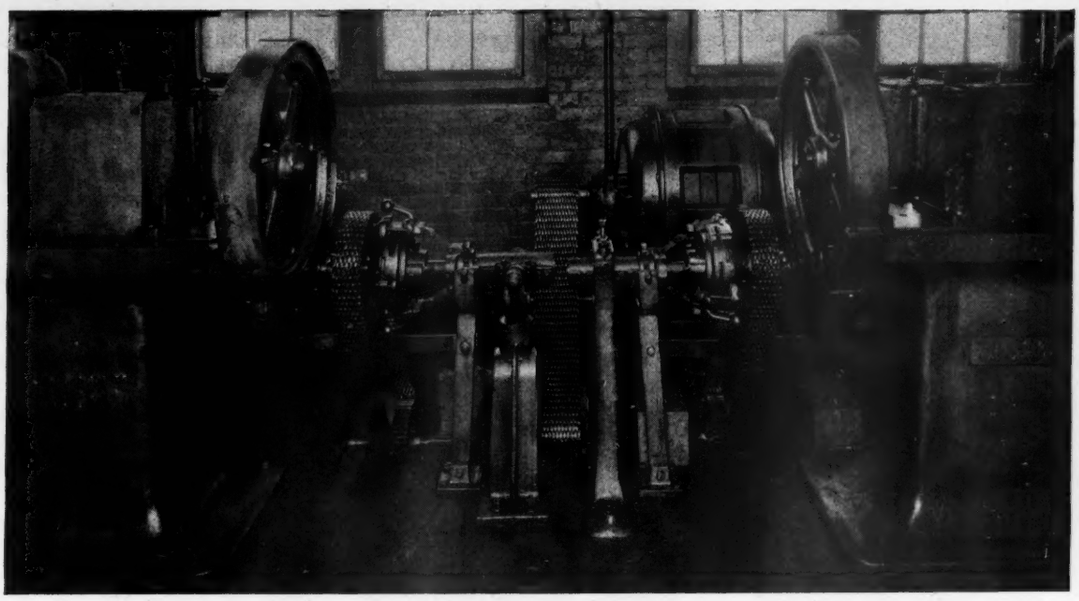
In most installations there is a considerable length of wire between the controller and the transformer, or generator, so that the impedance of the circuit is sufficient to limit the severity of a short-circuit. Where motor and control equipment is located close to a large source of power, such as may occur in a central station, additional precautions may be necessary to protect against short-circuit conditions.

If the line voltage fails, it is necessary to return the controller automatically to its initial starting position, so that the motor can be accelerated in the normal manner when power is again available. Two general types of devices are used for this purpose:

(*1*) Low-voltage release. This permits the motor to start automatically upon restoration of power. Pumps and air compressors are common applications for this type of protection.

(*2*) Low-voltage protection. This device prevents the motor restarting on restoration of power until the

(*Please turn to page 215*)



Here the motor drives the lineshaft beneath the floor through a Whitney silent chain. Each machine is driven from the lineshaft through a jackshaft with a clutch by a smaller Whitney chain.

Motor drives through

Worm Speed Reducers, Chains and Variable-Speed Transmissions

By GORDON FOX

Electrical Engineer,
Freyn Engineering Co., Chicago, Ill.

INCREASING use of high-speed motors has brought up the problem of connecting the motor to its driven machine or other load with an intervening speed-reduction device to obtain the proper operating speed. Previous articles in this series have discussed problems encountered with a motor drive through flexible couplings and clutches, where the connection is made without speed reduction, and also with belts, gears and speed reducers, which are used where a change in speed is desired. This article will discuss similar considerations involved in connecting a motor to its load through worm-gear reduction units, variable- or adjustable-speed transformers, and chain drives.

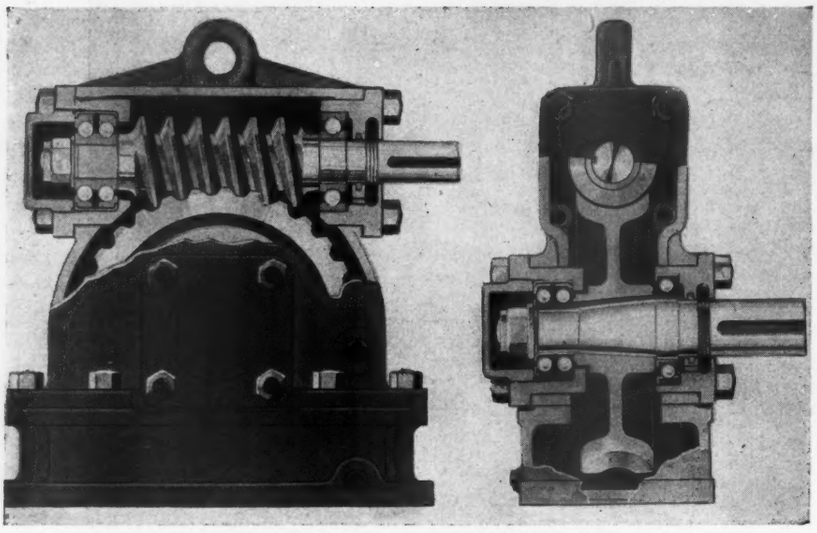
Worm gears are extensively used for motor-drive speed reductions. Sometimes they are a part of the driven machine but more commonly they take the form of a speed-reduction unit intermediate between the motor and drive. This type of unit is available over a wide range of sizes from fractional horsepowers up to 500 hp. Standard, single-reduction units afford ratios from about 5:1 up to 100:1. Double-reduction units afford ratios up to several thousand to one. Although worm gears are extensively used for low ratios, they are particularly advantageous for high ratios because of their relative simplicity.

Worm gear units are positive, quiet, and free from vibration. The driven shaft is at an angle of 90 deg. with the driving shaft. It is preferable that the worm mesh with the bottom of the gear, running in oil, which is thrown from the gear by centrifugal force into bearing troughs. If the worm is located above the gear it is more difficult to lubricate satisfactorily. Pressure lubrication, provided through the use of a small rotary pump and oil-circulating system, is particularly desirable for this construction, especially if the worm-wheel speed is high, because in such a case the oil carried up by the wheel, will be thrown off by centrifugal force before reaching the worm.

The worm produces an end thrust, requiring ample and well-adjusted, end-thrust bearings. Ball and roller bearings are frequently used, not only for thrust but also for radial load. A flexible coupling should be interposed to protect the motor from possible end thrust. It is desirable to mount the motor and the worm-gear unit on a common bedplate, where possible.

The best running surface speed for ordinary worm gears is about 300 to 500 f.p.m. The highest grades of modern wormwheel units are operated with running speeds of 2,000 f.p.m. and above. For such service the worm must be precision ground to secure uniformly distributed pressure and must be heat-treated to give a very hard surface with a low co-efficient of friction.

Worms with a helix angle less than about 10 to 12 deg. are not reversible



A complete ball-bearing installation on an Albaugh-Dover worm-gear speed reducer.

but are self-locking, in that the wheel will not drive the worm. Sometimes they can be used in a holding or self-braking capacity due to this feature. This relation is true only when the worm and wheel are at rest. When in motion it is entirely possible for the wheel to drive the worm without locking. This is due to the lower co-efficient of friction when running as compared with the co-efficient at rest. Thus it is possible for a motor to serve in a braking capacity against an overhauling load even with a worm drive of 10 to 12 deg. helix angle.

Reduction units for high ratios use single-thread worms of low helix angle, whereas gears for low ratios use worms with two or more threads and having a greater helix angle. Good efficiencies are obtained when the helix angle is above 25 deg. Worms with low helix angles have low efficiency because of the large proportion of sliding effect to rolling effect.

Efficiencies of worm gears are subject to wide variation, being dependent primarily upon the helix angle, the materials of which the worm and wheel are made, and particularly the kind, condition, and effectiveness of the lubricant.

During the last few years many manufacturers of worm gears have redesigned their equipment, adding ball or roller bearings, providing better facilities for lubrication, and using special alloys in both worm and worm gears. The worms are frequently heat-treated and ground. Special bronze or other alloys are used for the gear.

Units having helix angles above 25 deg. may have efficiencies ranging between 85 and 95 per cent. Self-locking units may have efficiencies between 65 and 80 per cent under load. The initial efficiency is well maintained over the life of the gearing. Units with low helix angles may require rather high starting torques because of the high static friction.

The horsepower ratings of commercial worm-gear reducers are nominal and are generally based on steady, uniform loads with little shock. The selection of a proper unit for a given application requires consideration of such factors as shock, peak loads, continuity of service, vibration, sudden starting and stopping, reversal, overhauling loads, type of motor, and prevailing load. Manufacturers' ratings must be discounted according to the service conditions. For very severe conditions it is necessary to select a unit rated at double the horsepower of the motor.

Temperature is often a limitation. Many worm-gear units are constructed with liberal oil reservoirs and enclosing cases to provide ample radiating area. However, for units of large horsepower rating, or for high ratios of lower efficiency, or where service is continuous, water-cooled housings may be necessary.

The oil level is important in any kind of speed reducer. If it is too low the lubrication may be unsatisfactory but if it is too high, churning of the oil may lead to heating.

For extremely high-reduction ratios a worm- and a spur-gear reducer are frequently connected in series. Reductions of 50,000: 1 have been obtained in this manner. Either the worm or the spur-gear reducer may be connected to the motor to drive the other reducer. These high reductions are commonly used on slow-speed conveyor drives, such as assembly conveyors.

The single-reduction worm unit is always a right-angle drive and so permits mounting the motor and the reducer alongside the machine it drives, thus conserving floor space. Practically all manufacturers will provide worm reducers with the worm either above or below its gear, or for vertical drives with the low-speed shaft extending either up or down.

Chain drives are also widely used for obtaining speed reductions. Both the roller and the so-called silent types of chain are well suited for many motor drive applications. Chain drives are positive, with a fixed ratio similar to a gear drive. Because of the positive action without any slippage or give, breaking or safety elements are necessary to protect the motor and chain wherever there is a possibility of sudden stoppage. Also, vibrations and shock loads require especial consideration with motor drives because of the limited flexibility of the chain. In the case of such loads the user will find it advisable to consult with the chain manufacturers.

An important advantage of chain drives is that the motor and driven shaft can be located on short centers, although a chain drive permits of greater leeway than gearing as to center-line distance and motor location. Chains are quiet in operation, due to the fact that the links have no sliding action on or off the teeth, and that the power is transmitted by all the teeth in the arc of contact. Such drives are reliable and are not subject to sudden failure. The operating efficiency is about 96 to 98 per cent and this efficiency is maintained throughout the life of the drive. Where necessary, in special cases, a chain drive permits of a change of ratio by a change of sprockets. Because no initial tension is required in the chain, the side and pull on the motor shaft is, largely confined to that produced by the transmission of power.

Roller chains may be used on drives operating up to 3,600 r.p.m. Silent chain drives have been used to transmit up to 5,000 hp., and on small units for speeds up to 5,000 f.p.m. The larger drives operate at relatively low rotative speeds and

use chains of large pitch; the high-speed drives are confined to lower powers, transmitted by chains of small pitch. There is a fairly definite limit to rotative speed for chains of each pitch and these limiting values can be obtained from the various manufacturers. When these limits are exceeded the drives become noisy and wear is more rapid. The rotative speed and diameter of the sprockets, rather than the linear speed, are the limiting considerations; a higher linear speed is permissible with a large sprocket than with a small sprocket.

The highest advisable speed ratio is 6:1 for large powers and 8:1 for small powers, although ratios of 10:1 and higher have been used successfully for drives where moderate chain speeds are employed. The minimum number of teeth in the pinions or smaller sprockets is rather definitely fixed according to the pitch of the chains. Thus, increased reduction ratios must be obtained by increasing the number of teeth in the larger sprocket. However, the more sprocket teeth in contact with the chain the less is the allowable wear on the joints before the chain will climb over the sprocket teeth. The life of the drive is more or less in inverse ratio to the reduction.

The first cost of chains is higher than for the belts or gears. Also, for safety, both to the operators and the drive, chains should be guarded. Usually a sheet-metal case is used which also serves to facilitate lubrication. Silent chain drives may be used for reversing service if the reversals are not too sudden and severe. Roller chains may also be operated in either direction.

The first factor governing the selection of a chain is the horsepower it must transmit. The value used should represent the maximum running load to be applied. Peak loads must be considered but occasional momentary peaks, except shock loads, can be handled safely as chains have an ample factor of safety. If regularly overloaded, chains will not give satisfactory service, however, due to rapid wear.

Where shocks are frequent, as with an air compressor or reciprocating pump drive, an oversized chain is recommended with an allowance of 20 to 50 per cent, according to the severity of the service. Some engineers question the use of chain drives on fluctuating loads, but there are many such successful installations. Sometimes a spring compensating sprocket is used to absorb the shock. It is generally better, however, to avoid load pulsations, where possible, through the use of sufficient flywheel effect.

Manufacturers of both roller and silent chain for motor drives issue tables and other data for use in selecting the proper chain for a particular installation. When making the selection the industrial engineer frequently finds that he has an option in choice between several chains, any one of which may be rated for the load; this choice lies between chains of different pitches, with correspondingly different widths. In such cases it is generally advisable to use the wider chain with the lesser pitch, although the narrower chain of longer pitch would be cheaper.

The width of the chain should preferably be from two to six times the pitch, but a range of one and five-tenths to ten times the pitch is permissible. Where very quiet operation is desired, as in an office building, wide chains of short pitch are used with 20 teeth or more in the smaller sprocket, operating at moderate linear and rotative speeds.

In determining the reduction ratio to be used a choice may be afforded in motor-speed rating. It may then be advisable to determine the combined cost of motor and chain drive for the different possible combinations. The lower cost of the higher-speed motor will be offset to some extent by the larger sprocket and longer chains required for the higher ratio. Such factors as motor duplication, efficiency, and power factor are usually more important than small differences in first cost; nevertheless, the possibilities for saving in first cost should not be ignored.

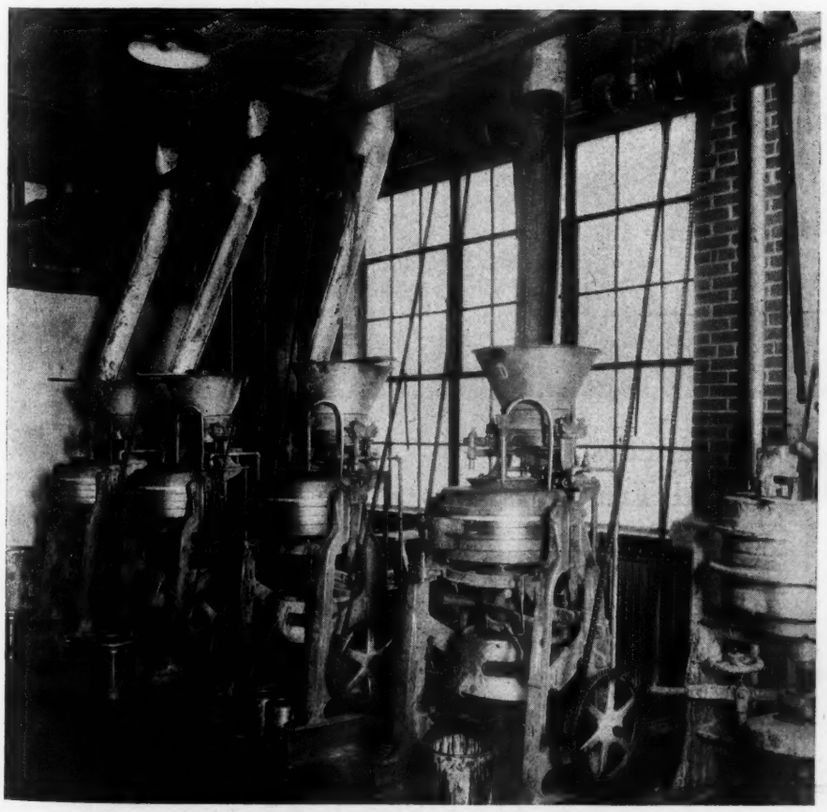
Where an exact ratio is not imperative, a slight variation may permit of a better selection of sprockets without using a sprocket with too few teeth or a chain of unsuitable pitch. Where clearances are limited, sprocket diameters must be selected accordingly.

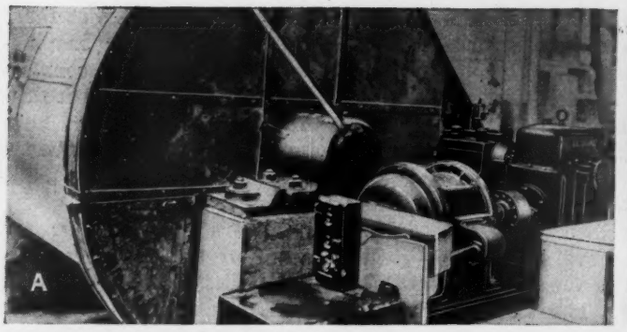
The proper selection of a chain to obtain the best possible service under a given set of conditions is a matter in which the chain manufacturers may well be consulted.

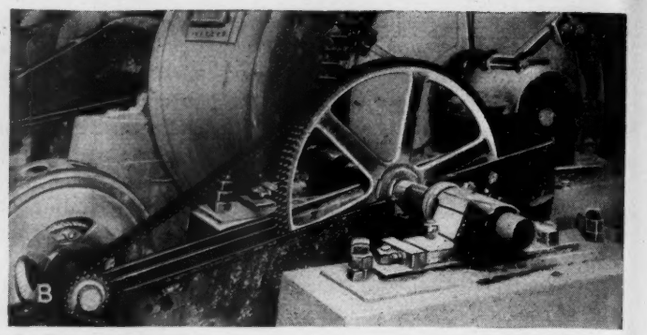
The center distance between shafts should be approximately equal to the diameter of the larger sprocket plus the radius of the smaller sprocket. This dimension may be moderately

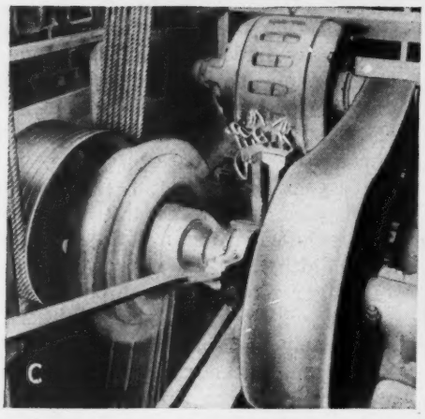
A combination of silent- and roller-chain transmission is used in this paint factory.

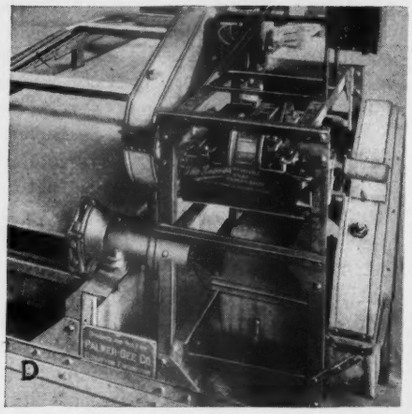
The lineshaft is driven from a motor by a Link-Belt silent chain and each individual paint mixer is driven from the lineshaft by a long Link-Belt roller chain. Each machine is cut in or out of service by Twyncone clutches.

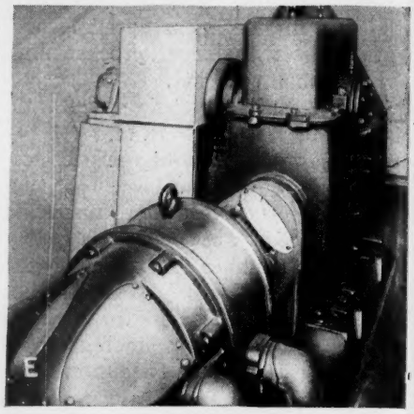


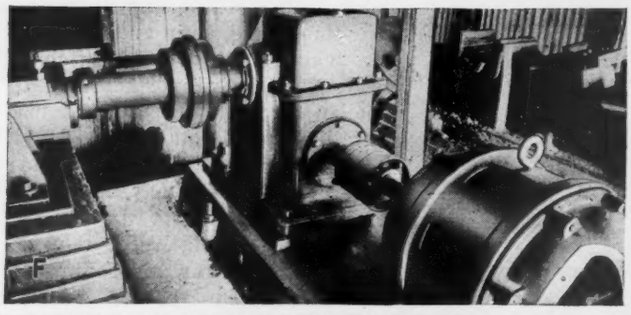


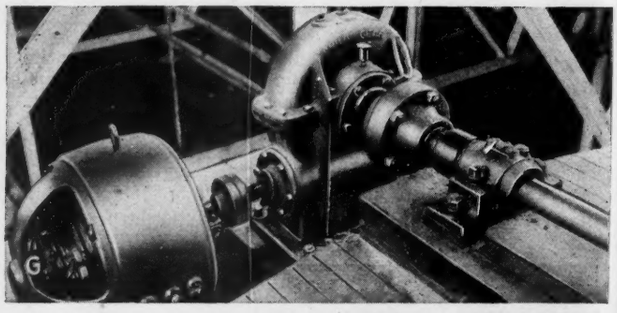


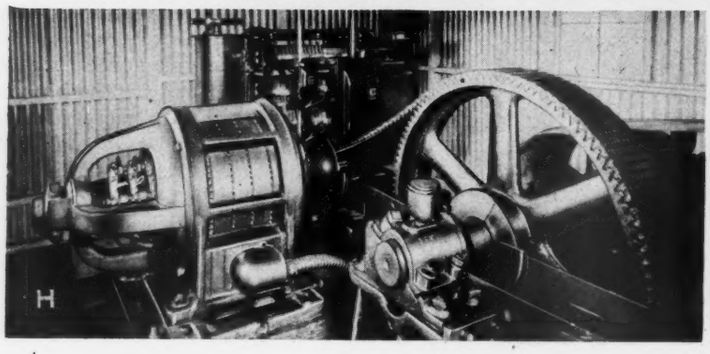


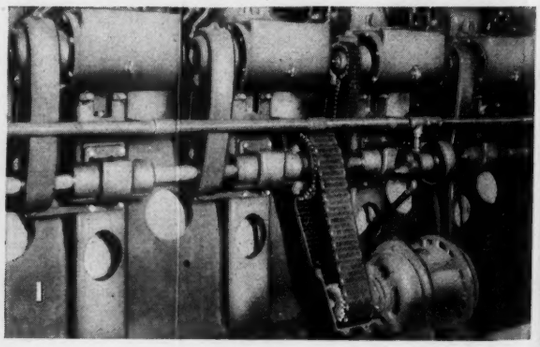












Nine Applications of Worm Reducers, Chains and Variable-Speed Transmissions

A—A compact installation of DeLaval worm speed reducers driving a pebble mill.

B—This 6-ft. Silex lime ball mill is driven at 30 r.p.m. by a 15-hp., 1,150-r.p.m. motor through a triple Diamond roller chain and a gear reduction. The chain gives a reduction from 1,150 r.p.m. to 146 r.p.m.

C—An American High Speed silent chain connected to an elevator drive operating under very dusty conditions. Here a 50-hp., 865-r.p.m. motor drives the shaft at 230 r.p.m. The center line distance in this case is 8 ft. 7 in.

D—Here an assembly conveyor in an automobile body factory is driven through a Reeves variable-speed transmission and a Palmer-Bee speed reducer. The three elements of the drive are connected by silent chains, which gives a very compact installation.

E—A 40-hp., 850-r.p.m., totally-inclosed motor drives this apron coal conveyor at a reduction ratio of 29½:1 through a Cleveland worm reduction unit.

F—Single-reduction worm gears give a right-angle drive which permits their installation alongside the equipment, as in the case of this Jones heavy-duty worm-gear reducer operating on a mine fan drive at a ratio of 8½:1.

G—This Philadelphia worm gear reducer is direct-connected to a 5-hp., 950-r.p.m. electric motor to drive a pulp agitator in a paper mill, at a reduction ratio of 35:1. Here the unit is placed out of the way and above the working floor.

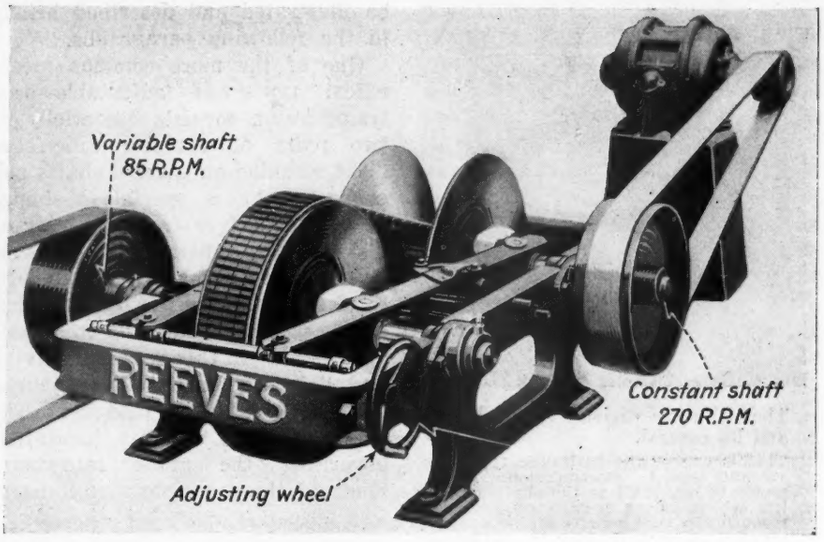
H—Link-Belt silent chain is used in connection with a variable-speed motor to drive the pumping rig countershaft at an oil well. These two shafts are mounted on 36-in. centers.

I—Morse silent chain connects the motor to this machine tool lineshaft, and six small Morse chains drive the various spindles on a gang drill. Each of these smaller chains permits the use of a shorter center distance than would be possible except with a train of gears. In this case the drive unit is mounted on the floor at the rear of the machines.

exceeded to advantage. However, with a long center distance on horizontal or slightly inclined drives, the weight of the chain tends to cause excessive tension.

Sometimes the centers on a high-speed drive are such that chain flopping synchronizes with load impulses. A small change of center distances by adding or removing links will usually correct the trouble. Chains increase in length due to wear. There should be no initial tension; neither should there be undue slack, as whipping of the chain also increases the wear. Means of adjustment are, therefore, desirable and a sliding base or rails are generally used under the motor.

Drives should preferably be horizontal or slightly inclined. Vertical drives should be avoided because they must be run rather taut and it is difficult to compensate for wear. For an inclined drive, the driving sprocket should be the upper one and the driven wheel should be flanged.



This shows the construction of the Reeves variable-speed transmission.

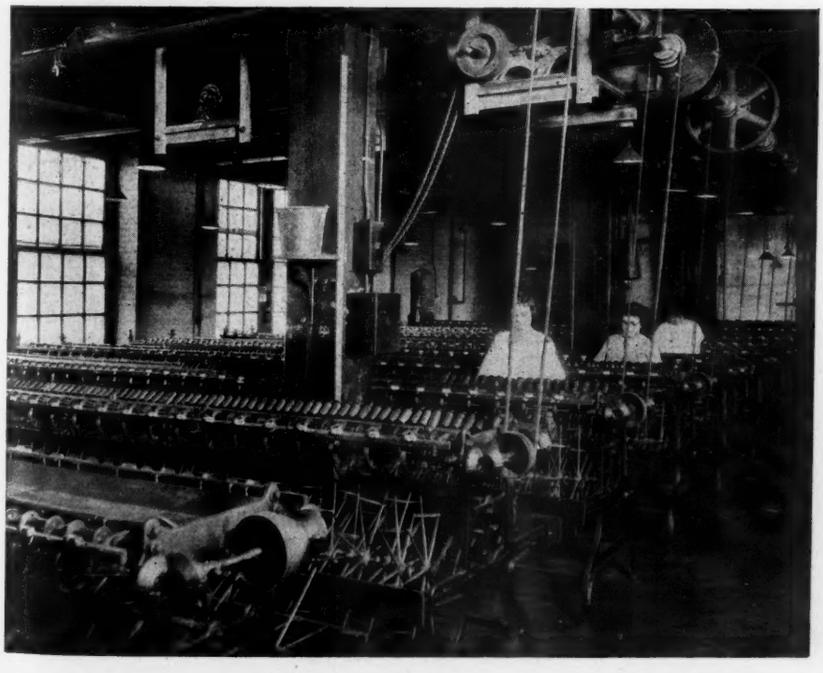
A constant-speed motor is connected to the input or constant-speed shaft by a belt or chain. Output of the variable-speed shaft is controlled by the adjusting wheel which shifts the relation of the cone-faced pulleys in the center to change the relative pulley diameters. In this case the pulley for the V-shaped belt on the constant speed shaft is at minimum diameter and the pulley on the variable-speed shaft is at maximum diameter which gives the minimum output speed. This is a 10:1-ratio, variable-speed drive and when the cones are shifted so that the constant speed shaft is of greatest diameter and the variable speed shaft is of least diameter, the maximum speed of 850 r.p.m. is obtained.

With ordinary horizontal or inclined drives up to 45 deg., direction of rotation may be such as to cause either the upper or lower strand to be slack. Where the centers are rather short, it is preferable to have the lower strand slack. If the slack is in the upper strand there is a greater possibility of the slack chain teeth being pushed out of proper engagement with the teeth of the driven sprocket. Drives with long centers and small sprockets should be run with the slack in the lower strand; otherwise there is danger of the slack, upper strand rubbing against the lower. With steeply-inclined drives it is generally best to have the slack in the strand having the lesser inclination.

Shafts should be level and sprockets must be in alignment and placed as close as possible to the bearings. The alignment may be checked by observing the guide links in the chain because when out of alignment, the wear on these links is not equally distributed on both sides.

An application of the Lewellen variable-speed transmission in a silk mill.

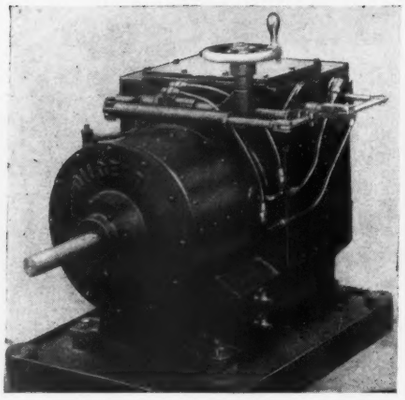
Here the motor is belted to the variable-speed transmission which in turn drives the lineshaft through a silent chain. In this instance the transmission is used for slowing down the silk throwing and winding frames when stopping, and for gradually bringing the frames up to the running speed when starting. When the operation is started at full speed, usually about 75 per cent of the fibers break and the operators lose from 1 to 3 hr. in getting all the fiber ends tied and the full frame in operation. With the Lewellen transmission, the shaft is slowed down before the motor is shut down and after starting at slow speed, the shaft is gradually brought up to full operating speed.



Silent chain wears at the joints. The usual life is said to be 15,000 to 20,000 hr. of operation, although this is often exceeded. Wear at the joints causes increase of chain pitch and the chain then tends to climb on the larger sprocket. Chain wear occurs primarily at the smaller sprocket and is emphasized if this sprocket is very small or the rotative speed is high.

Repinning with oversized pins, where possible, compensates for the wear in the links and brings the chain back to normal pitch. The cost of repinning is about 20 per cent of the cost of a new chain. The life of a repinned chain is estimated to be about 75 per cent of that of a new chain. Sprocket wear is usually small if the teeth are properly cut because the tooth pressure is distributed over a number of teeth.

Ordinarily the small sprockets are made of hardened steel and the large



The Oilgear variable-speed drive and its control.

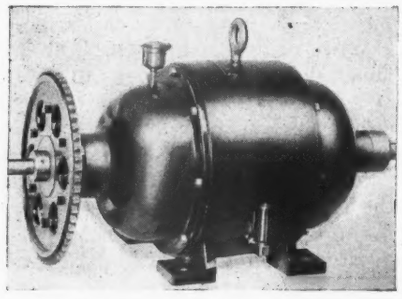
This is one of the hydraulic types of variable-speed transmission. The motor is connected to the shaft at the left which drives a variable-displacement pump that pumps oil to a constant-displacement motor in the opposite end. Any speed may be obtained from zero to the maximum input speed and in either direction of rotation.

sprockets are of semi-steel or cast iron. Chain links are heat-treated alloy steel. The pins are case-hardened nickel steel.

The various makes of silent chain differ primarily with respect to the joints; both pin-type and rocker-type joints are in wide use. The round-pin chains require oil lubrication, which is accomplished by running the chain in a bath of oil in an oil-tight case. Rocker-joint chains are lubricated with either oil or grease and should have a metal inclosure to catch the lubricant thrown from the sprockets and to exclude dirt as well as to protect the operators and the equipment.

This discussion has, up to the present, included only devices that give either no speed reduction, such as couplings, or a fixed ratio of reduction such as belts, chains, gears, and speed reducers. However, it is frequently desirable to obtain a variable or adjustable speed and at the same time use a constant-speed motor. Some of the mechanical devices that are available for doing this will be illustrated and described briefly in the following paragraphs.

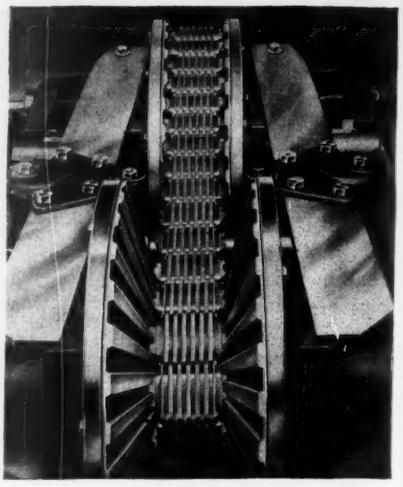
One of the more common mechanical types of adjustable-speed transmission consists essentially of two pairs of movable cone-faced disks mounted on parallel shafts and connected by a special, V-shaped belt which drives from one pair of disks to the other. Two pairs of levers, operated by right- and left-hand screws, move the disks so that as one pair separates, the other pair approaches; in this way the driving and driven diameters are changed and the speed ratio modified. The speed is regulated by a handwheel governing the above movement. Some of the accompanying illustrations show applications of this device.



One of the J. F. S. variable-speed transmission units.

The motor is connected to the high-speed shaft at the left. The slow-speed shaft at the right is provided either with an outboard bearing for pulley or gear connection, or coupling for torque load. The speed is varied by turning the wheel at the left. This is made in the form of a sprocket so that a chain may be attached for remote control. Change in speed is obtained by shifting rollers on a cone-shaped race.

This type of variable-speed transmission is available in sizes to about 150 hp. and for speed ranges from 2:1 to 16:1. Usually these units are connected to the motor by a chain that gives some reduction in speed. Often they are used with a speed reducer to obtain variations at very low speeds. Assembly conveyor drives are usually operated in this way; the speed of the conveyor is adjusted to give the desired output according to the number of men working on the assembly line.



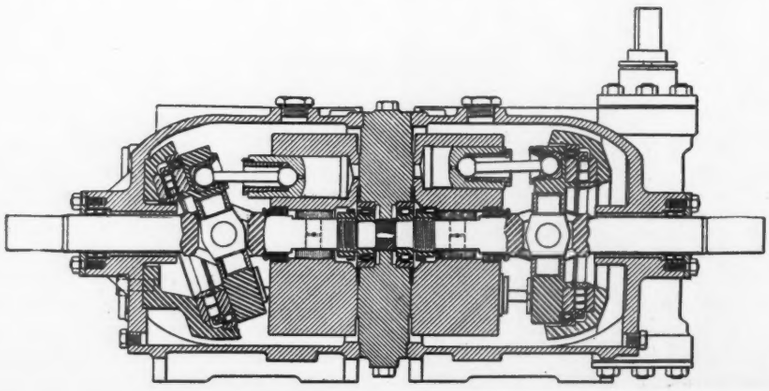
This is the P. I. V. variable-speed driving gear.

This variable-speed transmission consists of expanding pulleys of the opposed, conical-disk type which are connected by a special chain that fits into the ribbed or grooved disks. This transmission was described in more detail on page 98 of the February issue of INDUSTRIAL ENGINEER.

Slight shifting of the cones provides gradual speed adjustment in minute increments. This shifting may be controlled either automatically or manually, as desired. When equipped with ball bearings the efficiency is about 85 to 95 per cent at loads near capacity; the higher efficiency is obtained when the variable-speed shaft runs at high speed. At light loads the efficiency falls rapidly, due to fixed losses. The horsepower-transmitting capacity is greatest when the variable-speed shaft operates at maximum speed and falls off materially at lesser speeds. Hence, a knowledge of the load characteristics is important in planning an installation.

Other mechanical types of variable-speed drives are under development, and some are in operation in industrial plants on a wide variety of drives. A few of these will be illustrated and described in the accompanying photographs and captions.

Hydraulic types of variable-speed transmissions are also available. These usually consist of a motor-



Cross-section of the Universal hydraulic variable-speed gear.

These hydraulic units are made up to 200-hp. rating and will deliver any speed from zero up to input speed in either direction. The input at the left supplies varying quantities of oil to the variable-speed hydraulic motor at the right.

driven pump or turbine unit operating at motor speed that can be adjusted to circulate varying quantities of liquid, usually oil, to drive a companion unit at variable speeds, according to the quantity of liquid received. Most of these hydraulic units can be adjusted to deliver speeds varying from zero to the maximum speed of the input pump, which is usually motor speed, with an infinite number of increments in between. Also, the low-speed unit can be made to operate in either direction, although the input speed is constant and always applied in one direction.

The apparatus has a given torque capacity and will handle any torque up to rated value and at any speed. The horsepower capacity is proportional to the speed, and the efficiency is about 85 per cent at full speed and full torque. At reduced speeds and reduced torque the efficiency is lower, as the horsepower output is decreased and the losses are, therefore, of greater relative magnitude than at high speeds.

One make of hydraulic transmission, the Oilgear, has also been successfully applied as a means of translating rotary into linear motion. The pump member, driven by the motor, is connected with a cylinder the piston of which is moved at a speed corresponding to the pump displacement. This application has been made with particular success to broaching machines and hydraulic presses.

The hydraulic transmission gear has been developed in small sizes only in the United States but in England successful installations of similar character have been made on larger units. A mine hoist with a 200-hp., constant-speed induction motor drive was recently so equipped. The entire control of speed and rotation is obtained by adjusting the displacement of the pump member. One advantage of this application is the smooth acceleration obtained, with the motor running constantly at full speed and with minimum demand imposed on the power generating or distribution system.

The opportunities of using variable-speed transmission devices of both mechanical and hydraulic types have not been taken advantage of as extensively as may be possible when operating men fully understand and appreciate their uses, and the resultant advantages of obtaining and using exactly the best operating speeds.

Functions of Control

(Continued from page 208)

start has been initiated by the operator. Most controllers use this device as it is usually unsafe to have a motor start unexpectedly. A good illustration is a motor operating a machine tool or an elevator. In either case, the unexpected starting of the motor might cause serious personal injuries to someone using the machine or elevator.

Automatic contactor type control is usually arranged, so that it can be connected for either low-voltage release or low-voltage protection. Manual controllers may not provide a low-voltage device in themselves, and so may require additional control equipment to afford this kind of protection. The ordinary direct-current starting rheostat and the alternating-current auto-transformer starter have holding magnets that release the mechanism and open the circuit on failure of voltage from any cause.

Drum controllers should be provided with a protective panel for overload and low-voltage protection, as the drum controller does not usually provide such features in its own design. All safety codes dealing with this question require low-voltage protection for many applications.

Phase Failure Protection

Where the motor is connected to a polyphase source of power, an overload may be imposed upon the motor by one of the circuits being open. The most frequent cause of such failure is the opening of a fuse. If this occurs on a three-phase circuit, the motor will continue to operate at about 40 per cent overload on the single phase remaining in circuit. If the motor is fully loaded, this additional current should be sufficient to operate the overload device and disconnect the motor from the line. If the motor is operating on a light load, its windings will not be overheated and, from that standpoint, there may be no objection to its continued operation on single phase.

When one of the power wires is open, the single phase of the motor will generate a voltage between the open-circuited motor terminal and the other terminals, that will be nearly equal to the line voltage. This voltage is usually sufficient to retain any magnetic release in the closed position, so that a voltage coil usually will not afford protection against single-phase operation. A series coil can be used in each phase to protect against single-phase operation, but it is necessary to provide some special device to bridge out these relay contacts when starting, which adds complications to the controller.

The usual method of protecting against phase failure when the motor is running is to provide a torque device that operates like a small motor. Such a device can be wound and connected so that its torque will be decreased if one phase is open circuited, and it will thus afford protection against single-phase operation.

If the motor is at rest it will not start on single phase. It is easy to protect against this condition by ordinary low-voltage coils, as there is no voltage generated in the open circuit of the motor. Applications such as elevators, hoists, and the like, can have phase-failure protection in the off position that will prevent them from being burned out, due to this cause. Motor-driven pumps, fans, and so on, should either be protected by a suitable overload device or provided with a phase-failure relay.

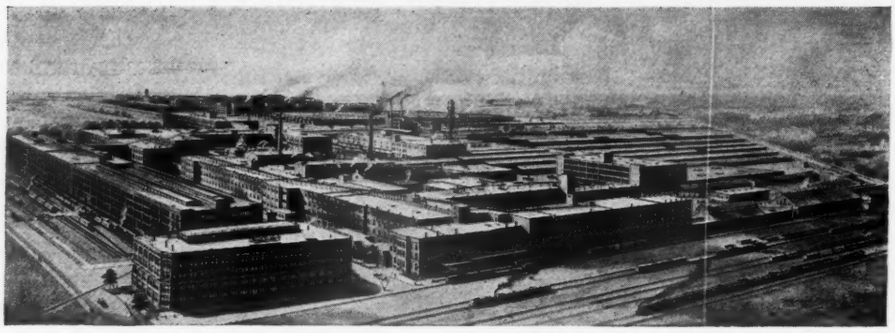
Sometimes the phase rotation in a polyphase power circuit may be reversed, by interchanging two leads at the transformer or somewhere else in the circuit. This reversal of phase may cause an accident to an elevator if its automatic stop device is so connected that it opens the wrong set of contacts. Such installations should be protected by a suitable relay. Thes relays are usually small torque devices that reverse their torque when the phase rotation is reversed. Relays of this kind are usually not necessary on other applications, as no dangerous condition is caused by phase reversal. They are, however, commonly used on certain types of elevator control.

In the above discussion a number of the more common functions of a controller have been pointed out. Other special functions may be performed when the application requires them. Each application should be analyzed and only the necessary functions specified for the controller. The simpler and less elaborate the control, the easier it will be to maintain and the less the initial cost of installation.

ORGANIZED PROCEDURE *in the South Bend Plants of the Studebaker Corporation for the*

Maintenance of Mechanical Equipment and Buildings

SECOND ARTICLE



By JOHN R. SULLIVAN

Supervisor of Transportation, the Studebaker Corporation, South Bend, Ind.

AT THE South Bend plants the Transportation Department controls and carries out the following activities: the interdepartment and interplant transportation of materials, products, and waste material; salvage work, which is largely transportation of scrap from the several buildings to a central point, from which it is handled by the By-products Division; general plant maintenance and upkeep; and plant railroad, including the repair and upkeep of track and yards, but not of locomotives. This article will cover only the work carried on by the maintenance division of this department.

Our maintenance work includes the following under the supervision of the foreman of maintenance: building painting, roofing repairs and renewals, floor repair, sewer cleaning, cleaning and repairing yards and roadways, concrete work, window washing, glazing, brick masonry, some janitor work, carpenters and handy men, labor gang, gardening and landscaping, railroad track maintenance. Approximately 60 men are employed regularly in this department. Frequently additional men, particularly laborers, are required on some of the larger jobs.

Roof Maintenance.—One of our most important jobs is in connection with the maintenance, repair, and renewal of the plant roofs. It is not the policy of the company to engage in extensive construction work. However, comparatively small jobs without unusual complications are usually performed by the company, much of it by our department, under the direction of the Construction Engineering Department. Two of the inspection engineers from the Construction Department also inspect all roofs and the whole of the foundry annually as a check-up on all building maintenance.

These inspections also back up recommendations where a department has not approved our report on the condition of the roof and need of repair. We make our own inspections and recommendations, which go with the estimated cost to the production manager and must receive his approval before the work is started. All work is done on instructions given on a regular repairs and renewals work order form and all labor and material charged against the division issuing the requisition.

The roofing gang consists of one first-class roofer, who serves as gang boss; three experienced roofers, and the necessary laborers. We have some slate and some gypsum tile roofing, although the larger proportion is tarred-felt paper, coated with asphaltum and gravel. The roofing men repair leaks and resurface or relay gravel roofs and replace broken slate or tile.

Another important part of the work is to keep the roof clean, as this not only gives the men a good opportunity to watch its condition and find small breaks, but also removes the dirt before it has washed down into the catchbasins. Approximately three gondola carloads, each holding about 40 cu.yd., are removed from the roofs monthly. The foundry roof has the largest amount of debris; a carload of material is removed from this roof every three or four weeks.

The roof on the Body Division, which has several dust and chip collectors for wood shavings, has the next largest amount of debris. This debris, which is largely sawdust, is transmitted pneumatically to the boilers along with all shavings and hogged woodwastes. Other buildings are cleaned regularly.

An important labor-saving device for removing the debris from the roofs is the use of galvanized-iron pipes or chutes extending from the roof down alongside the building. A 5-cu.yd. trailer is placed for the chute to discharge into. These trailers have metal coverings to prevent the debris from blowing about, as shown in accompanying illustration, and when filled are hauled away by tractors.

Window Washing.—All windows are washed at least four times on the inside and three times on the outside every year; no outside washing is done during December, January, and February. Windows in the

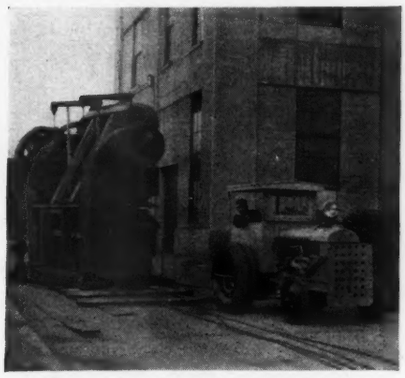
machine shop are washed every other month, however. No attempt is made to wash the windows in the forge shop, because of the heavy smoke and oil that settle on them. Window washing is a continuous operation and the men are on piecework.

A variety of cleaning agents are used in the different locations, depending upon the conditions. For example, the foundry windows are the most difficult to clean; hydrofluoric acid solution is used on them. Windows in the other divisions require the use of solutions that will remove lacquer, grease, and other deposits, each requiring some special cleansing agent.

The gang boss in charge of the window washers is also a glazier. At different times he has a gang varying from five to ten men help him. The entire plant has about 400,000 panes of glass and as many as 10,000 panes have had to be replaced during one year.

Building Painting.—The painting gang consists of about five men and a gang boss employed throughout the year. During part of the season about nine men are employed. Early in the spring the maintenance foreman and the inspection engineer from the Construction Department make an inspection of all outside work to see what will need repainting. The outside painting consists largely of upkeep on steel sash and frames. Most of the buildings are of concrete or brick with large steel sash windows. After the inspection and recommendations are made, the cost is estimated for each building, an appropriation is requested, and, with the approval of the production manager, the painting is done. Outside work is done in the summer and the gang works inside during the winter.

All inside painting, also, is done only upon the approval of the production manager. Wherever possible, the paint spray gun is used for



One of the miscellaneous big jobs handled.

This press weighs approximately 40 tons and was moved about ¾ mile. Part of the haul was made by putting the press on rollers on the railroad track and it was then pulled along by the switch engine. The remainder of the move was made by tractor as illustrated. The press was placed on skids and pulled along by a block and tackle.

inside painting. New construction is painted by this gang, and when a department is moved, we always try to get in and do the painting after all the old equipment is moved out and before the new equipment is moved in. In this way we overcome one of the most difficult problems in connection with spray painting—the necessity of covering up all machines and equipment. Ordinarily, where equipment is installed, it is necessary either to do brush painting, because of the difficulty of covering up all the machines, or to do the work at night.

Spraying, we find, can be done, where conditions are suitable, for about one-half the cost of brushing. Instead of erecting scaffolding, we have the painter, with his spray gun, stand on a platform built on a truck and be pulled along by a helper as he needs to advance. Wherever possible, we put both brush and spray painting on a piecework basis; at present about half of it is done that way. We have found that where the wall spaces are broken up too much or where too large an amount of wall or floor space must be protected, it does not pay to use the spray.

Our practice is to put three coats of paint on new work and two coats on old. We have standard outside and inside green paint for the sash and use a standard mill white for the ceilings and walls down to within 6 ft. of the floor. A battleship gray extends from there down to the 6-in. brown baseboard. Approximately 75 bbl. of paint are used a year for painting the buildings. Each job is planned two or three weeks or longer ahead, and so the paint is ordered as needed; thus we seldom have more than 2 or 3 bbl. of paint on hand at a time. This is in line with our company policy of keeping the stock inventory down to a minimum.

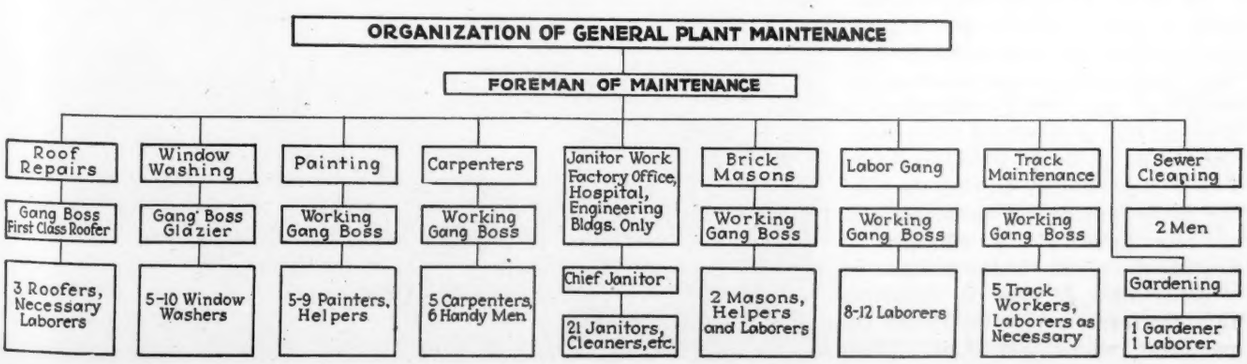
Steel sash is painted approximately every 4 yr. The length of time between paintings, however, depends on the conditions surrounding the windows. For example, windows exposed to condensate or to acid fumes require painting much more frequently.

Whenever possible, we try to clean walls instead of repainting. In many cases the walls will be fairly clean with the exception of a few dirty spots around some special machines mounted near the wall. In such cases we try to clean these spots frequently. In practically all cases these spots, particularly if they are grease or oil spots, must be cleaned before they are painted over. Where a large surface is to be cleaned, the work is done on a piecework basis.

One of the painters is a sign painter and letterer. An industrial plant, such as this, has many signs, notices, identification marks and numbers for machines, bays, and so on, around the plant. A large amount of this work was necessary in con-

Organization chart covering the general plant maintenance work.

This organization is a subdivision of the transportation department and on requisition does the necessary work within its line for both Body and Chassis Divisions.



Refuse from upper floors and roofs of the buildings is dumped down the chutes into the wagon.

The same method is used for disposing of scrap and metal turnings from the various floors, except that separate chutes are used for each material. The hood prevents the debris blowing about and is raised and lowered by means of a telescopic section on the end of the chute and counterweight. When filled, the wagon is removed by a tractor.

nection with a new storage building that was recently erected. When the man is not busy at this, he works with the other painters.

Carpenter Work.—Two divisions of carpenter and woodworking activities are carried on in our plant. One division, which includes the woodworking and cabinet shop, does all work that requires the use of machines. Much of this is new work, although part of it is for repair or maintenance of buildings and plants. The new carpenter work for the whole plant is described in an accompanying article.

Our carpenter work is almost entirely for maintenance or repair, although it does some new work, such as forms for machine foundations and for other concrete work. When we occasionally have jobs that require machine work, we have it done by this other department.

Ordinarily, our carpenter gang consists of six carpenters, six handy men, and a gang boss. The carpenters make all hardwood and creosote block floor repairs which may be due either to wear or changes in plant. The carpenters also build forms for new concrete construction and for the foundations for machinery. They erect and move partitions, wooden stockracks and bins, and take care of the multitude of miscellaneous carpenter jobs that are necessary in a large industrial plant. The handy men install, adjust, or change door or window hardware, adjust elevator gates, see that firedoors and other doors close easily, and do many other "handy" jobs about the plant.

All of the carpenter and "handy" work is performed only upon requisition on a repairs and renewals work order form with proper indorsement. Some of the work, however, is prompted as a result of the inspections made under the direction of the Power Department. During the winter doors that do not close easily or entirely increase the difficulty of heating the plant. If the foreman of a department is slow in reporting this, the inspector for the Power Department, whose task it is to keep heating costs down, finds the opening and reports it. The same is true of broken windows and other heat leaks. The repairs are made by some one of our gangs.

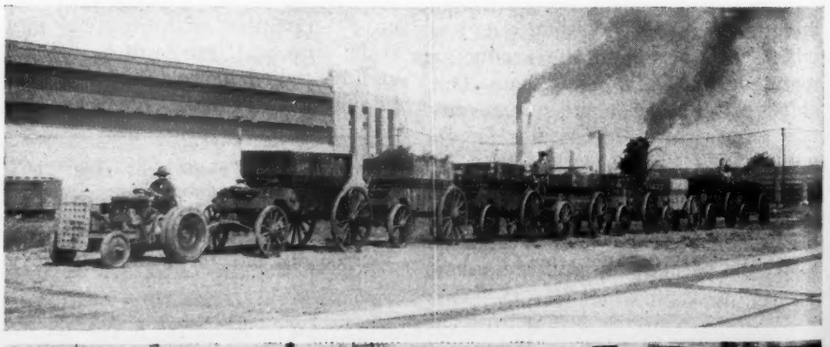
Brick Masons.—We have practically continuous work for three brick masons and three helpers under the maintenance foreman. These men reline heat-treating furnaces, the foundry cupolas, core ovens and other similar equipment using firebrick lining. They also cut holes in partitions or walls or erect new partitions. These men are all-around men and take care of the concrete work, cement finishing and plastering, with the aid of the necessary laborers.

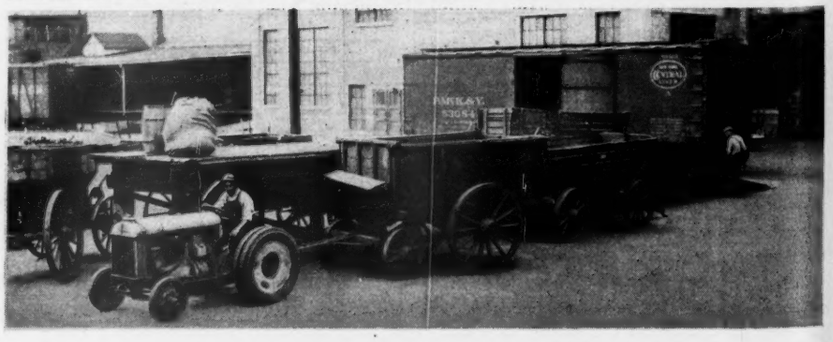
Sewer Cleaning.—This is a very important task. The amount of work required, however, is materially reduced by the frequent cleanings given to the roofs. Sewer work is done by two men working together without any gang boss or direct supervision. These men have been at this work for a long time and are held strictly responsible for conditions. They clean all inside and outside catchbasins, and follow a regular routine and repeat. They have to keep at it continuously and know that the results are strictly up to them.

Labor Gang.—The large amount of yard cleaning and the many miscellaneous tasks are taken care of by a labor gang. The number in the gang fluctuates according to the amount of work to be done. One of the regular activities of this department consists of cleaning the yards and roadways. This gang also removes the debris taken from the roofs and handles the salvage materials. Refuse from upper floors is dumped through chutes, which also handle debris from the roofs, into the trucks, as explained. However, sweepings and other material from the first floor and yard are wheeled up a yard ramp on wheelbarrows and dumped into a wagon alongside. One of these ramps is shown in an accompanying illustration. The wagons are hauled away by gasoline tractors.

Steps in the disposal of refuse and debris.

A gasoline tractor (upper view) with a train of trailers on the way to the dump with yard and roof refuse. Refuse from the first floor and from the yard is wheeled up this yard ramp and dumped into wagons alongside, as shown in the lower illustration. This takes care of material and wastes that cannot be sent down the chute.





One of the jobs of the labor gang.
This gang furnishes the labor supply for the miscellaneous odd jobs around the plant requiring a large number of unskilled men, but not in any way connected with production. In this case they are cleaning the mud from the spray cooling pond.

Approximately 50 to 80 cu.yd. of refuse are removed daily from the ramps. In addition to this about 100 cu.yd. of cinders are removed daily during the winter from the power house and 200 cu.yd. of refuse from the foundry departments. This latter consists largely of scrap core and molding sand. All roadways are swept by a mechanical sweeper attached to a gasoline tractor, as shown in one of the illustrations.

The labor gang also takes care of the removal of snow. Also, when we have a large concrete roof, or cleaning job, or any other labor job, these laborers are called on to assist in the work under the supervision of the roofers, masons, or other gangs. They are used on practically any type of work requiring a number of unskilled laborers.

Janitor Work.—The janitor work for each production department is taken care of under the supervision of the particular department. This gives the close supervision that is necessary. The refuse, floor sweepings, and metal turnings or borings from the different floors are dumped down chutes that have openings from the various floors to a wagon at the ground level, as explained. Separate chutes and trucks are used for refuse and for each of the various types of metal wastes, so that aluminum, steel, cast-iron, and brass turnings or borings are not mixed and so lose or decrease the scrap value. These metal wastes are all hauled over to the Salvage Department for disposal by the Byproducts Division.

We do, however, have a gang of about 21 day and night janitors to take care of the Factory Office, Hospital and Engineering Department buildings. This force takes care of about 175,000 sq.ft. of floor space. Each janitor has a definite routine to follow with certain fixed work to do, and the work is on an hourly basis.

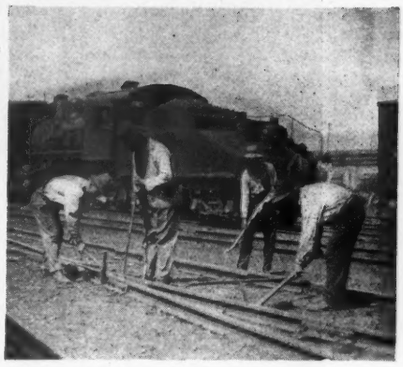
Track Maintenance.—We have our own railroad and switching facilities and have about nine miles of track. Crossings, frogs, ties, and loose spikes and bolts are looked after by a gang of five track workers. This, of course, is increased if any extensive changes are to be made.

Gardening and Landscaping.—During the summer one man devotes practically all of his time to taking care of the lawn and other green spots about the plant. Part of the time this gardener is supplied with a laborer to help him. During the winter he is put in one of the gangs as a helper.

Cost Keeping.—Work is not done unless on the requisition of a department approved by the division superintendent, and after this requisition has also been approved by the production manager. An exception is made for requisitions that would involve a very small amount, such as fixing doors or windows and other items not exceeding $25 in cost for both material and labor. All items costing over that must have the approval of the production manager. Each order for work done is issued on a repairs and renewals work order form and given a job number. The men working on each job indicate the job number on their time cards. The labor cost is apportioned to the various departments after the cards go through the Timekeeping Department. The necessary materials are supplied on a stock requisition issued against this same order number. This also is charged by the Cost Department against the particular job number.

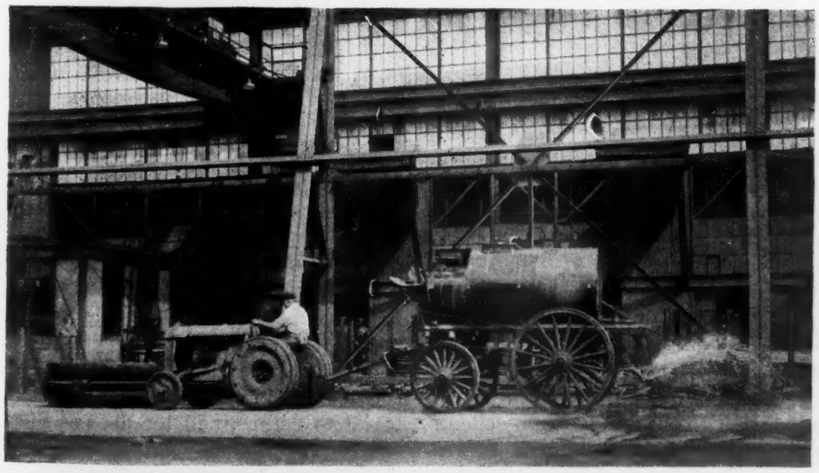
Work involving a considerable expenditure is always estimated ahead of time, and the estimate is approved by the department head. It is our problem then to keep within the estimate. These orders are handled through the Estimating, Routing and Inspection Department, which issues the necessary purchasing requisition where new supplies must be purchased. However, an attempt is made in all cases to use materials that are purchased for the Production Departments and are kept in our regular stock. Although the maintenance division of our department has its own storeroom, the supplies in this are kept at a minimum and in many cases, as in painting jobs, only the amount of supplies required and issued for a particular job are kept on hand.

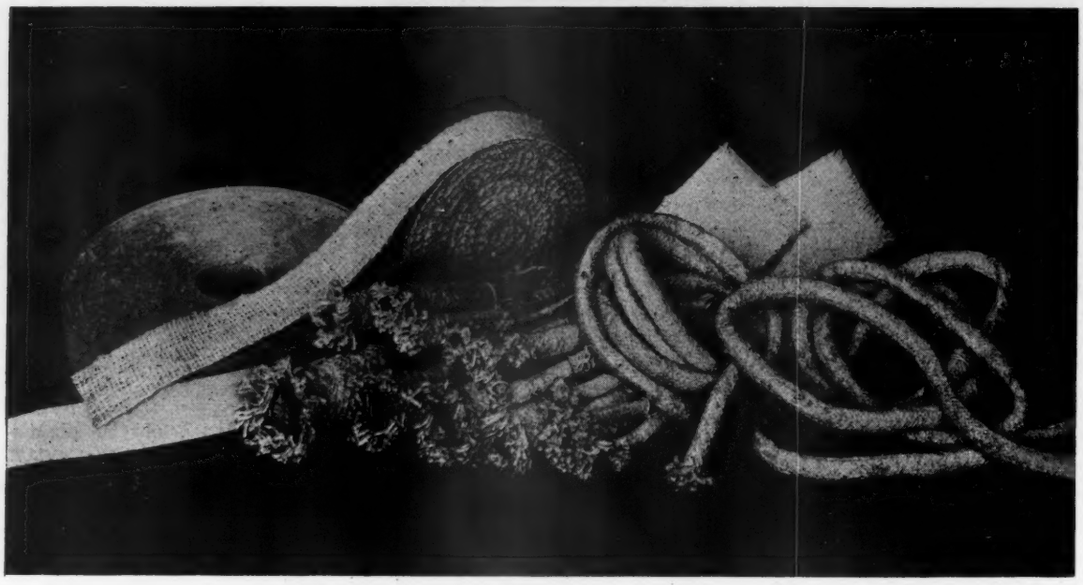
As the work done is always charged back to the department for which it is performed, we are watched very carefully to see that the cost of any work is not what that department considers too high.



Maintenance of the plant's railroad track keeps a foreman and four men busy.

Yard and street cleaning is still another duty.
This mechanical brush, pushed by a tractor, does the work of a large gang of laborers. The sprinkling cart settles any dust that is not swept up. The dust is also removed regularly from the roofs.





This shows some of the forms in which asbestos insulation can be obtained. Courtesy the Mitchell-Rand Manufacturing Co., New York, N. Y.

Heat-Resisting Insulation

For Protecting Windings Against High Temperatures

By A. C. ROE
and
D. H. BRAYMER
Consulting Editor, Industrial Engineer

WHEN motors must operate near objects that radiate heat, such as hot rolls in steel mills, hot kettles, ovens, boilers and the like, and when they are called upon to carry overloads continuously during certain periods, the insulation to be used in a rewinding job requires careful consideration in its selection and application. This is particularly true in instances where the load on a motor has been changed from intermittent to continuous, such as increasing the number of lifts per hour on a crane motor, or when a motor designed for open duty is totally inclosed for operation in dusty surroundings.

In some cases the use of more copper in the coils will help to reduce the operating temperature, but in nine jobs out of ten, the use of high-heat-resisting insulation is required to prolong the life of the motor after rewinding. For full protection against high temperatures the insulation should be of inorganic composition, such as mica, asbestos, Bakelite, and so on or a combination suited to the operating conditions.

In the November issue of INDUSTRIAL ENGINEER the use of asbestos-covered wire was discussed. In this article the practical application of asbestos in other forms as an insulating material for windings will be taken up from the standpoint of high-temperature protection.

Asbestos is found in the fissures of certain serpentine rocks and cleaves in great quantities of small fibers. The characteristics of the fiber depend upon its source, some varieties being long, delicate, flexible and elastic, while others are short, stiff, and brittle.

There are two kinds of white asbestos used as motor insulation. One is lower in silica, lime and iron content than the other, but higher in magnesia and water. This is the kind most commonly used for electrical insulation. Although the other grade is slightly more heat- and acid-resisting it is rather brittle and for this reason is not used so much. White asbestos furnished for electrical work contains between 13 and 14 per cent of water in chemically combined form. It is the presence of this water that prevents asbestos from being fully fireproof. In case asbestos is subjected to a red heat the water is driven off, inducing brittleness and flaking which, if carried far enough, injures the asbestos to such an extent that its value as an insulation is impaired and it must be renewed. Asbestos may, therefore, be injured by a red hot fire, but it prevents the spreading of fire. That is, it will not carbonize and burn as would organic material, and it will not be affected by heat alone.

The color of asbestos ranges from pure white to green, blue, yellow, pink, and light brown. The long fibers are carded and spun into yarn by a process similar to that employed in the manufacture of cotton or wool. This yarn is then used in weaving asbestos cloth or tape, or braided into sleeving. Cotton is added to provide strength to the asbestos threads while spinning and weaving so that reasonable speed may be maintained in the manufacturing processes. The amount of cotton in any piece of asbestos material is determined by the combustion process and is called the carbon

content, 2.2 per cent of cotton being equal to 1 per cent of carbon, approximately.

From the above it is obvious that the quality of asbestos products can vary. For instance, in asbestos sheeting or paper there may be present some iron compounds that would greatly reduce its dielectric strength, and in some cases make the material unfit for use as insulation. In tape or sleeving if the carbon content runs high and a piece of electrical apparatus is subjected to high temperature a failure is likely to happen at a critical time.

Many manufacturing companies make tests to determine the grades of material they require and then write up purchasing specifications which indicate the kind and quality of asbestos required. These specifications give values for yards per pound, threads per inch, carbon content, tensile strength, and other requirements.

The inspection departments use the specifications to pass or reject incoming asbestos materials. Since asbestos products are expensive, and any piece of apparatus insulated with them represents a considerable cost, it follows that only the best grades of materials should be purchased, and only from a reliable source.

Asbestos Tape Insulation — Asbestos as applied to stator, rotor and field coils is used in the form of tape, sleeving and sheeting, or as asbestos paper. The tapes can be obtained in thicknesses of 0.015, 0.020, 0.025, 0.035, and 0.063 in. and in widths of 0.5, 0.75, 1.0, 1.25, and 1.5 in. for the 0.015-, 0.020-, and 0.025-in. thicknesses; 0.75, 1.0, and 1.25 in. for the 0.035-in. thick, and 0.5, 0.75, 1.0, 1.5, 2.0, and 3 in. for the 0.063-in. thick. The best sizes to stock for general repair use are 0.75 and 1.25 in. in the 0.015-in. thickness.

The 0.75-in. width, 0.015 in. thick, is used for armature coils, while the 1.25 in. is more suitable for field coils. Where the application is mostly for armature or stator coils a stock of 0.015 in. thick and 0.75 in. wide can be carried and used on field coils. In fact the 0.75-in. width will give a tighter lap, but will require a little more time to apply. However, the reduction of inactive stock will more than offset the small extra labor item.

The use of 1.25-in. tape is preferred to the 1.5-in. for field coils, since the 1.25-in. provides a tighter lap, which means that the finished coils will have a better seal. This can be proved by taping a straight bar with 1.25-in. and 1.5-in. tape half overlapped, both tapes being applied with the same degree of tension. Then pick up the edge of the lap with the finger nail, which will show that the 1.25-in. tape is tighter than the 1.5-in.

Another reason for specifying 0.015-in. thick asbestos tape for armature and stator coils is that in the majority of cases the finished tape originally used on the coils that are being redesigned with higher temperature-resisting insulation is 0.007-in. thick cotton tape, and since this tape is usually half overlapped on the ends, there would be a total of four thicknesses or 0.028 in. of cotton on each coil end. With the thinnest asbestos tape half overlapped we would have four thicknesses or a total of 0.060 in. which would tighten up the end windings, and if end space is limited it may be necessary to just barely butt the asbestos tape. That is, leave a small space $\frac{1}{64}$ in. between each turn of tape, which would reduce the total thickness to 0.030 in. of asbestos tape.

Three Ways to Make Coils for High Temperatures

[1] Increase the copper area and use asbestos-insulated wire.

[2] Use asbestos-covered round, square or ribbon wire with mica wrapper and asbestos tape.

[3] Use bare copper strap coils, mica-taped with mica wrapper and asbestos tape.

The method to use will depend on the operating conditions. Study each case and apply the heat-resisting materials best suited to these conditions, as explained in this article.

Asbestos tape when applied to coils as a finishing tape has a ragged appearance with small particles or ravelings sticking up somewhat like lint on cotton goods. If the coils are dipped in this condition the finished coils will have a ragged look and the projecting pieces will be hard from soaking up the varnish. There are two ways to overcome this. One is to hot-press the coils in the slot sections and rub the hand over the ends, which will knock off most of the loose projections. The other is to rub and trim off all loose projections or ends by hand. This is another item to watch in buying asbestos tape, as some grades may have more loose ends or ravelings than others, particularly at the edges of the rolls. In some cases these ends do not show up until the tape is being unrolled. Anyone who has unrolled straight-cut friction tape and had it ravel will understand what takes place.

The number of threads per inch and the weave have considerable effect on the strength and ease of application of asbestos tape.

Asbestos Sleeving—This form of asbestos is used as lead coverings. The wall thickness and inside diameter of this sleeving vary with the different manufacturers. Some grades are coarse and have as high as $\frac{1}{16}$-in. wall thickness, whereas other grades can be obtained with a wall thickness as low as $\frac{1}{32}$ in. Two sizes, $\frac{1}{8}$-in. inside by $\frac{3}{16}$-in. outside diameter, and $\frac{1}{4}$-in. inside by $\frac{3}{16}$-in. outside diameter, are the best sizes to stock, as these will cover the majority of wire sizes.

When using asbestos sleeving it should be cut into the shortest lengths possible. After putting it over the wire, pull it out and fasten both ends with glue. There are two reasons for this. The first is that asbestos is expensive and stretching the sleeving means economizing in material. The second reason is that in pulling the sleeving up tight the bulk is reduced, thus allowing the leads to be put down without crowding.

Asbestos sleeving can be checked by the number of yards per pound and the number of threads. The yards per pound is important, inasmuch as sleeving is purchased by the pound, but used by the yard. If the wall thickness is excessive there will be less yardage, and a bulky job will result.

To check the number of threads, cut off about 1 in. of the sleeving and stretch or work it until the threads separate; then pick the piece of sleeving apart, one thread at a time, and count off the threads. Next, cut off 1 lb. and check the number of yards in a pound. Put these figures on record for future checking.

Asbestos Paper—Asbestos paper is a combination of asbestos fiber and paper, compressed but not sized. Asbestos paper should be carefully selected to avoid the presence of

small particles of iron oxide or magnetite like scale or grit in the fibers. Although these are very small particles, a microscopic inspection of the paper will in some cases reveal several such particles per square inch.

This paper can be obtained in various grades, according to the carbon content. In this class we have asbestos paper tape. This material is better than the sheet material since its carbon content is lower and it will stand higher temperatures without carbonizing.

In most cases the tensile strength of asbestos paper in sheet or tape form is very low and it should not be used as a binder for the outside finish of stator or armature coils. It can, however, be used for the outside finish on small magnet coils and the like.

The major use of asbestos paper or paper tape is between turns of strap-wound field coils. For this purpose the material should not be less than $\frac{1}{8}$ in. wider than the copper strap, nor thinner than 0.007-0.010 in. or 0.015-0.020 in. These are the sizes that are most frequently used.

The following simple precautions should be taken when using asbestos paper or tape between turns of strap copper coils: First, keep the paper dry. Asbestos is hygroscopic and will absorb considerable moisture in the ordinary storeroom; therefore, any coil wound with asbestos paper between turns should be thoroughly dried before being dipped in varnish or impregnated. If the coil cannot be dipped and baked, the material should be placed in an oven and dried and used as needed.

This applies to such types of apparatus as the revolving fields of two-pole turbo-generators—those having horizontal slots in which the copper strap is wound directly with asbestos between turns. It is obvious that these slots are deep and if any moisture is present in the paper, it would be an extremely hard matter to drive it out; if it is not driven out it will be the cause of serious trouble. In cases of this nature put the asbestos paper in an oven and bake it dry. Keep it under heat during the day so that each roll of material used will be bone-dry.

Asbestos string or cord can be used for bands, tying coils and filling the back of commutator necks.

When rewinding electrical apparatus for operation at higher temperatures, we have the following conditions: (1) Cases where an increase in copper area and the use of asbestos-insulated wire will reduce the full-load or operating temperature to a degree that will permit the use of cotton finishing tape with a mica wrapper. (2) Cases that will require asbestos-covered round, square or ribbon wire with mica wrapper and asbestos tape. (3) Bare copper strap coils, mica-taped with mica wrapper and asbestos tape.

On direct-current armatures, or wound rotors for alternating-current motors, inorganic material should be used under bands, core insulation, and so on. Also, pure tin solder should be used to fasten the bands and leads in the commutator necks.

When armatures or rotors have fiber retaining wedges, these should be left out and band grooves cut in the core to provide for core bands. Stator wedges can be made from slate, ebony, asbestos, transite and the like. The lead jumpers, star connections, and so on on stators should also be covered with asbestos insulation.

As already mentioned, asbestos is expensive both as a material and to apply; so each job should be studied and the material used in a manner that will do the most good. For instance, do not half-lap the tape if slightly spacing it, say $\frac{1}{16}$-in., will do. Do not use round wire and asbestos tape if the use of square wire will reduce the temperature.

Combination Mica and Asbestos Paper—Another asbestos material is a combination of mica and asbestos paper. This has a layer of mica between two layers of asbestos paper and is used between the sections of strap-wound field coils. It has high dielectric strength as well as high-temperature-resisting qualities. When these materials are used the finished coil should be treated with a baking varnish that will not run under high temperatures and that has a heavy body.

Asbestos fibers are combined with synthetic resins to make molding mixtures that set on the application of heat and in their final state are resistant to high temperatures, oil, and acids, and in addition are waterproof.

Liquid Bakelite, which is a synthetic product, is a varnish-like liquid that hardens under the application of heat. After it sets heat will not soften it even though it be heated to a carbonizing temperature. This material has high mechanical strength and heat-resisting qualities and can be used to impregnate asbestos wire coils. When hot-pressed it will hold the wires together, or the finished armature can be dipped in liquid Bakelite.

Do not dip and bake finished coils, as this will cause them to become too hard to handle. If apparatus is too large to dip, the coils can be dipped in Bakelite and allowed to air dry for a few hours; then put them in the machine in the green state and bake the complete apparatus. Asbestos paper when impregnated with Bakelite becomes brittle and unless the paper is well supported, Bakelite should not be used with it.

Some Don'ts When Using Asbestos

[1] Do not allow asbestos insulation to absorb moisture. When using it be sure that it is bone-dry.

[2] Do not half-lap asbestos tape when a spacing of $\frac{1}{16}$ in. will be satisfactory.

[3] Do not use round wire and asbestos tape when square wire will reduce the operating temperature sufficiently.

[4] Do not dip or impregnate coils insulated with asbestos until they have been thoroughly baked.

[5] Do not use a cheap grade of asbestos; the best grade economically used and properly applied is the cheapest in the end.

Legibility of Color Combinations Used on Danger Signs

TO THOSE interested in the legibility of "danger" signs, here is the net result of an investigation conducted to determine the relative values of colors in order of legibility, as given in *Town Topics* (Thomas Insulator Co.): (1) Black letters on yellow background. (2) Green letters on white background. (3) Blue letters on white background. (4) White letters on blue background. (5) Black letters on white background. (6) Yellow letters on black background. (7) White letters on red background. (8) White letters on green background. (9) White letters on black background. (10) Red letters on black background.

Operation and Care of Storage Batteries

IN ORDER to deliver the service that it is capable of rendering, a storage battery must be given a certain amount of careful attention. The consequences of neglect may, for a time, be slow in appearing, but eventually the battery will be ruined or get into such bad condition that costly repairs will be required. On the other hand, attention to a few simple details will not only prevent trouble but very materially lengthen the life of a battery. The instructions given in this article are from the Manual of Storage Battery Practice of the Association of Edison Illuminating Companies, presented at their forty-second annual meeting.

THE most common causes of plate trouble in storage batteries are short-circuits, abnormal sulphation and impurities in the electrolyte. Short-circuits may result from the positive and negative plates coming in contact by buckling; by the displacement of the small hanging lugs, or from particles of lead or other metals lodging between them from spongy growths or from scale on top of the plates bridging over between them; and from sediment in the bottom of the tanks accumulating sufficiently to touch both positive and negative plates.

If a short-circuit is caused by buckling or breakage of plates, the trouble should be remedied by replacing the separator, or possibly by inserting a strip of thin wood, in addition to the old separator, at the location of short-circuit. When the plates are in such condition that the trouble cannot be permanently overcome, it will be necessary to replace them. Straightening of plates has been tried at various times, but the operation has been found to be rather unsatisfactory.

Small pieces of metal may occasionally fall into a cell and by lodging between the plates cause a short-circuit; this is particularly likely to happen at the time when the plates are burned in, either during installation or when subsequent repairs are made. For this reason careful inspection should follow the work.

After a battery has been in service for some time, there may appear a deposit of spongy lead on the top of the negative plates, due to excessive charging or a deposit of scale on the positive plates. This deposit should be removed before a sufficient quantity accumulates to bridge across the plates.

Loss of Active Material from Plates

In proportion to the amount of work done by the battery, the positive plates lose their active material, which falls to the bottom of the tank as sediment. Tanks are built with a space under the plates sufficiently deep to receive all the sediment that will be deposited during the entire life of one set of positive plates. In stand-by batteries a 6-in. sediment space is considered sufficient. In batteries that are in active service, with old style tanks that have shallow sediment space, it is necessary to keep a check on the depth of the sediment that accumulates. and remove it before it touches the bottom of the plates and short-circuits them.

The presence of a short-circuit in a cell is indicated by its behavior as compared with other cells. Its specific gravity will fall off, its voltage will drop below normal, there will be some rise in temperature, and the cell will be slow in gassing or will not gas at all on charge.

A simple method used for detecting short-circuits in a cell is to measure the voltage drop across the connecting lug of the negative plates with a millivoltmeter. A cell having an internal short-circuit will give a slight indication across the lugs of the plates which are not in trouble and a very much greater indication across the lug of the plate in trouble. When the negative plate that is short-circuited is determined, the two positive plates adjacent to it are tested for the exact location of the short-circuit. The separator is then pulled out, the short-circuit cleared and the old separator, or a new one if necessary, installed.

This reduces the amount of labor in the clearing of short-circuits. With close checking of the specific gravity, individual cell voltage and temperature, and the use of the above method of clearing trouble it is possible to maintain the cells without a large loss in capacity, oftentimes eliminating a separate cell charge. A millivoltmeter with a low scale is satisfactory for this purpose. When measuring the lug drop, the first contact must be made at a point somewhat above the electrolyte level and the other contact then made at the top of the lug. If the reverse order of making contacts is followed there is danger of damaging the meter, from the lower prod touching the electrolyte.

Cells that have been short-circuited should receive a separate charge sufficient to restore them to normal condition, after the cause of the trouble has been removed. The active material is partly sulphated, which is a normal condition, but when a cell does not receive sufficient charge to reduce all the sulphate formed during the discharge or by local action, there is a gradual increase in the amount of sulphate until it assumes a hard, crystalline form unmixed with active material. This condition is termed abnormal sulphate. Hard sulphate is a poor conductor of current, and when abnormal sulphating has occurred, a charge extending over a long period at a low rate is required to reduce the sulphated material to normal condition. Conditions of operation that produce abnormal sulphate are: Standing discharged for a long period, habitual undercharging, the unnecessary addition of electrolyte instead of water to replace evaporation, and neglect of short-circuited cells.

Effect of Foreign Substances in Electrolyte

Certain foreign materials that may enter the electrolyte increase the action upon the plates considerably beyond normal, reducing both the capacity and the life of the plates.

Iron in a cell discharges both the positive and negative plates, by being deposited on them and creating local action. If it is present in sufficient quantity, it seriously attacks the positive plates and materially shortens their life. The presence of

iron may be detected by a light yellow coloring of the positive plates and a strong odor.

When copper is present in the electrolyte it is deposited upon the negative plates and forms local elements which discharge the plates. The presence of copper is indicated by liberation of gas at the negative plates when the cell is not charging, and by a copper coating on the lugs.

The effect produced by chlorides or nitrates is an increased formation of material on the positive plates, shortening their life and in some cases resulting in their buckling.

It is detrimental to the plates if the fumes of muriatic acid or ammonia are allowed to enter the battery room and remain there any length of time. Batteries located near chemical works are especially exposed to this danger.

Cause of Failure to Deliver Rated Capacity

The failure of a cell to deliver its rated capacity may be due to the natural wearing out of either the positive or the negative plates, or to any of the causes mentioned in the preceding paragraphs.

The plates will give rated capacity as long as they have sufficient active material in good condition, and in the proper state of porosity and contact. The natural wear of positive plates consists in the gradual loss of active material; that of the negative plates, in the loss of contact and porosity by reason of shrinkage of the active material.

Under some conditions it may be expedient to make partial plate renewals. Plates of like polarity of different age or design should not be installed in the same cell. The positive and negative plates, however, may be of different ages.

There is a gradual lowering of the specific gravity of the electrolyte due to minute quantities of acid being carried off with the gassing spray on each charge, and to the sediment that accumulates in the bottom of the tanks absorbing some of the acid. These losses must be made up, but only at long intervals or when the gravity, with the battery fully charged, has fallen 30 points (0.030 sp.gr.) below normal. To raise the gravity, add new electrolyte of normal strength when replacing evaporation, repeating until the gravity of the cells is restored to normal, after which water should again be used for replacing evaporation. Acid of a density higher than 1.300 specific gravity should never be added to the cells, as electrolyte or higher densities has been found to be detrimental to the plates. In purchasing acid, however, a saving can be effected by procuring acid up to 1.600 specific gravity, which may be reduced by mixing with water and which is safe to handle in the mixing process.

Inasmuch as certain impurities in the electrolyte are detrimental to the plates, special care must always be taken to insure that both the acid and the water used in the battery are suitably pure. Local water may or may not meet the requirements. The suitability of either acid or water always should be passed upon by the battery manufacturers, who will analyze samples free of charge. This applies also to electrolyte in cells in which impurities are suspected. Not less than eight ounces of electrolyte or one quart of water are required for analysis.

If harmful impurities are present in a cell, the safest procedure is to remove the electrolyte immediately, flush the cell thoroughly with water and refill with fresh electrolyte. This new electrolyte should be of the same specific gravity as that drawn from the cell and adjusted if necessary to normal gravity after the cell has been given the proper charge.

Maintenance and Repair of Battery Tanks

The subject of battery maintenance concerns the life of the tanks as well as that of the plates. This is especially true of batteries in stand-by operation where long life of plates may be expected. Plates that are considerably aged may not bear handling, although if not disturbed they would last for a much longer time. Therefore, if for no other reason, tank renewals and repairs should be kept down to a minimum.

To obtain the greatest life from wood tanks, it is important that the battery room be kept as dry as possible by proper ventilation and care, and that the battery be equipped with cell covers. Overflowing cells when adding water should be avoided.

The tanks should be painted with a good grade of asphaltum paint at the time of installation, and should be repainted whenever the coating shows signs of deterioration. Raw linseed oil acts as a preservative and a light coating should be occasionally applied to the tanks. If the wood checks from shrinkage, the openings should be filled with thick paint or with compound. In old tanks the woodwork is likely to open up at the dove-tailing and, if taken in time, may be repaired by bracing with insulators or by banding.

Leaks in tanks are caused by punctured linings, seam holes and electrolysis. Punctures arise from accidents or carelessness in handling. Electrolysis is caused by electric leakage from the cell to ground, as a result of the insulators becoming coated with a film of acid or dirt, or being broken. Electrolysis is more likely to occur on the positive side of a three-wire system battery with a grounded neutral, as the lead linings of these cells are positive to ground. These troubles are not common in present-day practice where oil insulation is used. Seam holes are due to improper lead burning.

Minor leaks can usually be repaired by a lead patch, but frequently electrolysis may have advanced so far before being discovered that it may be necessary to put in a whole new bottom lining, extending several inches up the sides of the tank. The wood of the tanks becomes more or less soaked with the acid that has leaked through the lining, and before relining the acid should be neutralized with air-slaked lime and the wood dried and painted. The insulators should be kept free from dirt and acid film. Cracked or broken insulators should be replaced.

It is recommended that air-slaked lime be used on the floors to offset any acid spray or drip from the cells. Air-slaked lime absorbs the moisture and neutralizes the acid. A thin layer spread on the floor under the tanks and about 2 in. into the aisle from the tank will be found to be satisfactory. This keeps the floor dry.

Protection of Copper Work Against Corrosion

The care of the copper work in battery rooms is mainly a matter of cleaning and preventing any products of corrosion from falling into the cells. Copper parts should be painted with white lead or coated with heavy oil or grease as a protection against the acid spray. The use of heavy oil or grease, while satisfactory as a protection against corrosion, has the disadvantage of being unsightly and of collecting dirt and dust. The copper-supporting structure should be protected against acid fumes by the application of acid-resisting paint. The practice of applying acid-proof compounds on horizontal metal parts of the battery has been found to be satisfactory.

An operator's viewpoint on

Industrial Equipment Advertising

used by manufacturers, with some comments on its value as pre-purchase information

DURING the time I have been writing this page for INDUSTRIAL ENGINEER, many mighty fine letters have been received telling about interesting experiences, the problems confronted, and the features that are right and wrong about machines, men, and all other things that enter into the life of the operating man. These letters have reflected experience, lots of it, and a careful digesting of the material appearing in this publication, from cover to cover. That is to say, the advertising pages get a thorough going over: so thorough, in fact, that errors in statements or impressions are frequently mentioned.

In this connection you will be interested in the following comments on advertising by E. J. Morrissey of Aurora, Ill., who is one of our readers and an old-time operator:

LET me say at the beginning of this letter that the first knowledge that I had of Practical Pete's existence was when the mailman laid INDUSTRIAL ENGINEER on my desk. Therefore, neither Practical Pete nor I can be accused of a conspiracy or collusion in the writing of what is to follow.

As I glance through the pages of trade and technical magazines, I am very much impressed by the quantity of advertising used by manufacturers of industrial and power plant equipment and supplies—somehow or other it not only furnishes an idea of their size but of their growth as well. As the months pass by, I also note that a growing number of bulletins of individual firms make their way to my desk, not to speak of the great influx of calendars and the like that appear at certain times of the year.

I believe that we have one of the most modern and up-to-date plants in the country, with efficiencies and economies that our load and conditions warrant, and it is not a peculiar fact that practically all, if not all, of our equipment was purchased from manufacturers whose advertising can be found in the most conspicuous places of nearly every publication I receive.

Very often the manufacturer also uses a useful item to keep his product before us. There is the diary of one company, the notebook of another, a handbook from the third: letter openers, ash trays, blotters, bulletins, line books and a variety of miscellaneous articles that perform a useful function in ordinary life and serve as a real advertising medium that means money well spent. And yet we find a few who confine their efforts to sending calendars only, with the perfectly natural result that if all the calendars received in many offices similar to ours were used for their intended purpose there would be enough to paper the wall three deep. This does not mean that we do not appreciate the efforts of these manufacturers. I can assure you that every legitimate piece of advertising is appreciated and very often is a real source of information.

With reference to advertising pages, it is a disappointment to a reader of a magazine to pick up a late issue and feel so sure he knows what advertisement the X & Y firm are running that he is willing to bet with his friends on it. Advertisements go stale with the operator, if they are not changed and made informative.

There was a time when "the best mouse trap" could be manufactured in the woods, but nowadays it is necessary to beat the track to the buyer's door. This can be accomplished through live advertising in the magazines, or by helpful aids, and through personal solicitation.

I believe the greatest disappointment I ever noted in advertising was the short-sightedness of a large firm that manufactures a good product. I had occasion to use quite a number of their units and wrote for a catalog and parts list. Nothing was forthcoming until a second letter elicited the statement that they had forwarded these items to our purchasing agent. Now, we have a very estimable purchasing agent, but how in the world could they expect purchases of their equipment to originate if I, as the user, could expect no more attention. On a purchase order I would surely be out of luck—and so would that firm.

Advertising can be a decided waste, regardless of cost, or it can be one of the few items that will serve to bring about a better understanding between the manufacturer and purchaser, through its pre-purchase educational value. For this reason every operator should read the advertising of the firms makthe equipment he uses, or contemplates purchasing.

WE WELCOME letters from our readers, giving the operator's viewpoint on every phase of plant work. We want to help you with your operating troubles, buying problems and requirements, and all questions relating to plant operation and maintenance. If you have any ideas, experiences, or questions, that you want to pass along, write to me and I'll put them up to other operators for their comments and suggestions.

Practical Pete

INDUSTRIAL ENGINEER
Devoted to the Maintenance and Operation of Electrical and Associated Mechanical Systems in Mills and Factories
G. A. VAN BRUNT, *Editor*

Paint Is an Important Factor in Industrial Lighting

THE dingy factory with bare lamps or poorly designed shades hanging close to the operators is still far too common. Comfortable lighting is impossible in such interiors because the lamps or lighting units are glaring against dark backgrounds. It is becoming realized that paint is a valuable ally in making the lighting comfortable. If painted white the walls, and particularly the ceiling, need receive only a small quantity of light to aid materially in reducing glare.

Some modern industrial lighting units have been designed to permit a small percentage of the light to escape upward. Where such units are not used, the small amount of light reflected upward from the floor and other objects illuminates the white-painted ceiling sufficiently to reduce the glare of the lighting units. This is the chief function of white ceilings from the viewpoint of lighting when the level of illumination at the work is only a few foot-candles.

As higher levels of illumination are desired the ceiling must play a greater part. At the present time a factory with 10-foot-candles at the work-plane is out of the ordinary, but the student of lighting knows that levels as high as 20 to 40 foot-candles are economically desirable. Some are already looking toward levels as high as 50 and even 100 foot-candles.

To obtain such levels without utilizing the ceiling as a secondary light source will likely be unsatisfactory from the viewpoint of eye comfort. The day has arrived for seriously considering the importance of well-maintained white ceilings which may provide an appreciable indirect component in industrial lighting. This is thoroughly practicable in many industries.

Separate Maintenance From Production

IN SOME plants it is still the practice to have maintenance taken care of by production men. This is wrong from several viewpoints, as a recent instance shows.

Operation of several unloaders used for removing coal from boats at a large coke plant was at first attempted on the hit-and-miss system of having on each unloader an operator who was supposedly responsible for getting his share of the boat unloaded. This arrangement soon resulted in the boats being unloaded so slowly that in several cases demurrage charges were incurred. It did not take the management long to find out that a good dock superintendent was required to oversee the operation of the unloaders and other equipment on the dock.

The production man placed in charge of this work was so successful in getting the boats unloaded that complete supervision of the dock equipment, including electrical and mechanical maintenance, was given to him. Soon, however, the management began to complain about heavy repair costs on the unloaders. There were innumerable armature changes, many rewind jobs, gears broke, and so on.

What was the trouble? Simply that maintenance was being sacrificed for production. As the dock superintendent was primarily responsible for production, he sacrificed the equipment in order to get production.

This usually happens when the production superintendent also discharges the functions of a maintenance superintendent. Maintenance should be in charge of a man who will stand up and fight for the proper operation and care of equipment. It may be possible to kill two birds with one stone, but in this instance the chances of doing it are very slight.

There Are Definite Reasons for Chronic Motor Troubles

THE squirrel-cage induction motor is about as simple in construction as anything that has yet been devised for a power drive and when properly applied gives less trouble than almost any other piece of electrical machinery. When misapplied and abused, however, it may show such a variety of distress indications as to puzzle experienced motor men and cause no end of worry and repair expense.

Motor trouble often occurs on installations in which the manufacturer furnishes a direct-connected motor with the machine he makes and this complete machine is sold by a representative who knows more about his machine than he knows about electrical equipment and the varying conditions under which the motor must operate. When motors are used with a rating close to the brake horsepower demanded by the machine, or under rated voltage, crowding a machine only slightly beyond its rating through the working of different materials may result in motor heating that cannot be blamed on the motor. Such conditions may at times be severe enough to trip overload control devices and tempt the operator to set them beyond the safe limit for the motor. A breakdown in the coils or a burnout is the natural result.

When troubles are experienced with induction motors, the safest way to proceed is to get a

graphic meter reading of the ampere or kilowatt demand of the motor over a period long enough to include all conditions under which it is operated. If the trouble is in the motor this record will show it in such form that it will be easy to convince anyone of the reliability of your test. If the graphic record does not show that the trouble is in the motor, then look for it in the driven machine and the conditions under which it is operated. In nine cases out of ten when the size of the motor is adequate, the source of the trouble can be located in the carelessness of someone who installed the machine or is operating it, or else the machine is doing work for which it was not designed.

Under such conditions the electric motor is simply the safety valve or distress signal and does something for the machine that the latter cannot do for itself. Oftentimes it requires more commonsense than technical knowledge to discover this fact and apply the remedy.

Standardization of Machine Speeds Will Simplify Operation

A STEP that is now being taken toward the standardization of machinery speeds will be watched with interest by all industrial operating men. This move has recently come in the form of a request made by the National Electrical Manufacturers' Association to the American Engineering Standards Committee to take up the matter.

Under present conditions there is an endless variety of sizes of pulleys, gears, sprockets and other auxiliary transmission units which the manufacturer, jobber and dealer must keep in stock in sufficient quantity to supply any probable demand. The user must also keep a variety of such parts on hand, many of which are not interchangeable or usable anywhere except on the original installation.

As matters now stand, the curve of the speeds of driven machinery is practically a random distribution without any logical order. Although the need for simplification of the speeds of driving and driven units has been apparent for years, without co-ordination and national standardization no satisfactory solution could be reached.

It is to be hoped that standardization will result in a comparatively small number of co-ordinated speeds for the almost innumerable kinds of machinery. This would help to solve the problem of simplification and standardization of pulleys, gears, and so on, would permit greater flexibility in the selection and use of power units and driven machinery, and promote interchangeability of units. At the same time, many industries that are dependent on the manufacture and use of such equipment would be able to effect worth-while manufacturing economies.

Operating men in many plants have already standardized on motor and lineshaft speeds, and frequently have changed pulleys on purchased machines to make them conform to these speeds. Oftentimes special equipment has been required, but where a sufficient amount of equipment can be standardized it has always paid because of the convenience in making changes.

Relief from the nightmare of odd and special sizes of power drive equipment will be welcomed by every plant operator.

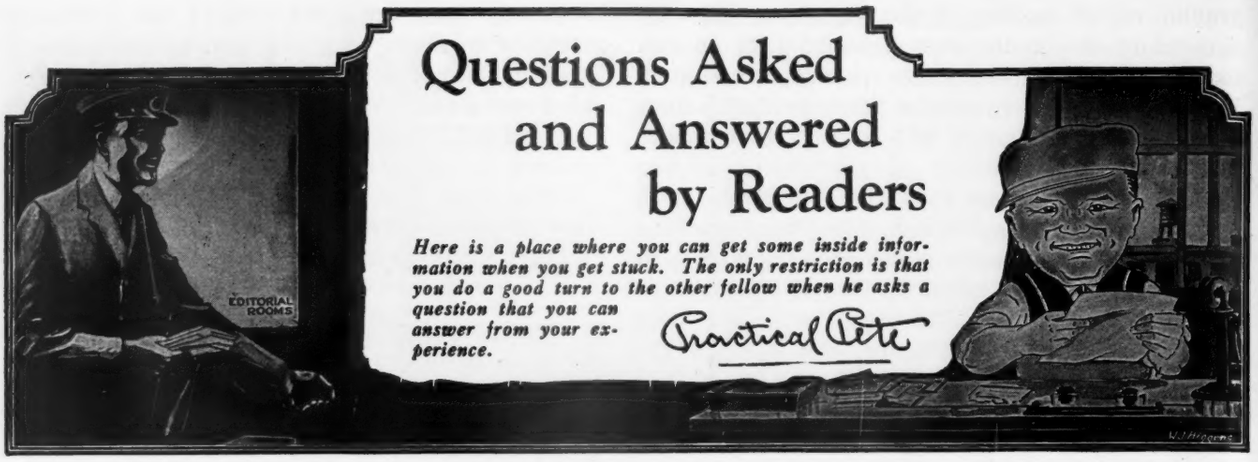
Show Your Men How to Lubricate New Equipment

PERHAPS no other single factor in industrial operating conditions is so important as lubrication. Manufacturers of practically all types of equipment are today redesigning their products to improve the bearings and at the same time provide for more reliable lubrication. The application of ball or roller bearings and improved splash and circulating systems for speed reducers and enclosed gear drives, are examples of what is being done along this line. The desire to reduce friction is only one of the reasons for these changes. Simplification of the lubrication problem is practically as important as the saving of power; this is the condition in at least a large percentage of instances.

Some industrial operating men, however, apparently still believe that if a small amount of lubricant is good a large amount is better. With the old type of loose-fitting bearing the important factor was to have a supply of lubricant always feeding down into the bearing. The exhaustion of this supply was generally fatal to the bearing.

In the lubrication of many types of modern equipment the lubricant is used over and over because the dust-tight inclosures keep the lubricant and bearing surfaces free from contamination. In a number of instances, however, users have complained of serious heating. Investigation has shown the cause to be too much lubricant in practically every case. Thus, in one plant a number of worm-reducer drives were heating because the gear cases had been filled to the top with oil. Ball or roller bearings with the grease chambers packed full under pressure will also heat, without apparent cause.

Such troubles are obviously due to the fear of the old-time employee that the small amount of lubricant recommended will not be enough. Operating executives in charge of power transmission equipment can well afford to take a few minutes to explain the changes in lubrication methods and requirements that have been brought about by the development of new types of bearings and improvements in old designs. It is no longer necessary to "oil every day to keep trouble away." It is essential, however, that the oiler understand what too much lubricant, as well as too little, will do, and why.



Questions Asked and Answered by Readers

Here is a place where you can get some inside information when you get stuck. The only restriction is that you do a good turn to the other fellow when he asks a question that you can answer from your experience.

Practical Pete

QUESTIONS

Who Can Answer These?

Calculation of Multiplier for Portable Graphic Wattmeter

I want to use a 5-amp., 110-volt, 2,400-kw. scale graphic wattmeter in connection with 100 : 1 ratio current transformers. What meter constant will result when using 3,200-kw. paper? What formula may be used to determine constants on meters having other than 5-amp. coils, when using different combinations of current transformer ratios, scales, and paper? B. U. D.
York, Pa.

Eliminating Dead Spots in Squirrel-Cage Motor

We converted a General Electric, form L., internal-resistance type induction motor to the squirrel-cage type by cutting out the resistance and short-circuiting the two-circuit star rotor connections. When starting with the compensator dead spots are encountered. I wish some one would please tell me how to overcome this trouble. L. J. L.
New York, N. Y.

Relation Between Power Factor and the Coal Pile

In trying to improve the operating efficiency of our plant a question has come up regarding the effect of power factor. We generate our own power and use about 600,000 kw.-hr. annually. Our generating and distribution equipment is of ample capacity, although we are operating at a power factor of only 65 per cent. I understand the effects of low power factor on the distribution system, but should like to know just how it affects the coal pile. I wish some reader would explain this, as I want to determine whether it will pay us, from the standpoint of fuel economy, to raise our power factor to 90 per cent, or thereabouts. E. A. W.
Toronto, Can.

Repulsion-Induction Motors Fail to Start

Several new ¼- and ⅓-hp., 110/220-volt, single-phase, repulsion-induction motors operated satisfactorily for a few months, but now they either fail to attain full speed or refuse to start even under no load. Sometimes when the armature is turned over so that the brushes touch a different bar, the motor will start. The commutators are not rough or badly blackened, and tests indicate that the motors are in good condition. A receiver test, made when the short-circuiting device is removed, indicates that there are no open circuits in the armatures. Dead spots on the commutator do show up, but when it is turned over a few bars, these dead spots give a good test and the parts which previously indicated a good test give a poor one. Operating these motors under ideal voltage conditions does not help to cure the trouble. Will readers please suggest the cause and remedy for the trouble with these motors?
Quebec, Can. W. S. B.

What Causes Blowing of Fuses on Transformer Bank?

We have two 50-kw. transformer banks serving separate heating loads and when they are connected in parallel on the secondary side the fuses blow on one bank. Everything on the nameplates of both banks corresponds except the polarity. One bank is marked Subtractive, while the other is marked Additive. Will readers explain the meaning of these markings, and tell me if this difference in polarity has anything to do with the blowing of the fuses? H. B. D.
Lynn, Mass.

Installing Anti-Friction Bearings in Sleeve-Bearing Motors

We have a large number of induction motors of modern design, ranging from 10 to 75 hp. in size, that are fitted with ordinary sleeve bearings. Many of these motors operate in a very dusty place and considerable trouble has been experienced from rapid bearing wear. On all of our motors we have had trouble with oil slinging, which has caused a number of failures. For these reasons we are considering installing ball or roller bearings. Accordingly, I shall appreciate it if readers will tell me (1) their experience with these bearings and (2) give me some information on how to install them in place of the present babbitted sleeve bearings. (3) Can you give me any data on the cost of making such a change? L. M.
Joplin, Mo.

Cutting Out Damaged Coil in Winding

Will some reader please give me a diagram of a chorded split loop winding showing the method of cutting out a damaged coil? I should also like to know if this type of winding does not have a much longer lead throw than the straight loop winding. Can it be wound with two wires in hand and connected to a commutator with twice as many bars as coils? Would the method of cutting out a coil be the same as when wound with one wire in hand? J. B.
Los Angeles, Calif.

ANSWERS

Received to Questions Asked

Effect of Doubling Speed of Lineshaft

We have a lineshaft operating at 250 r.p.m., driving a number of woodworking machines. I am considering doubling the speed of this lineshaft: that is, increasing it to 500 r.p.m. This will give a better belt drive from the motor to the lineshaft, as then I will not need to use so small a motor pulley. Also, a number of the pulley ratios from the lineshaft to the jackshaft will be changed, as I am going to increase the speed of most of the machines only about 30 to 50 per cent instead of doubling them. There is no noticeable vibration in the lineshaft at present. As nearly as I can determine from computations, however, the shaft is well loaded at the present time and I should like to know what the effect will be when I increase the speed, and whether I might have to put in a new shaft, assuming that the present shaft is carrying full normal load for its size and speed. I shall greatly appreciate any information that readers may give me on this problem. G. G. K.
Milwaukee, Wis.

INASMUCH as G. G. K. has not given the size of his lineshaft, number or kind of machines being driven, or the horsepower of the motor, it is quite difficult to advise him intelligently, although a few points that should be of some value to him are as follows:

(1) To increase the speed of the lineshaft will require more power.

(2) When the lineshaft is speeded up, it must be better balanced in order to obtain as smooth operation with no more vibration at the higher speed.

(3) For the sake of safety, discard all wood pulleys that are larger than 18 in. in diameter, and replace them with steel ones. E. L. WAY.
Ada, Ohio.

IN REPLY to the question by G. G. K., a well erected lineshaft should stand the increased speed without trouble, although if any defects are present in the shaft, a breakdown is more likely to occur than when the shaft is operating at the lower speed. Any trouble would be more likely to develop at the supporting bearings than in the shafting itself, for these

were probably designed and erected to support a shaft to be run at 250 r.p.m. They might stand the increased speed without much trouble, but if overloaded as well, serious overheating and damage at the bearings would result. All bearings should be kept under constant observation for overheating immediately after the alteration, for the risk of breakdown will naturally be increased at the higher speed and some minor alterations at the bearings may be found necessary. W. E. WARNER.
Shefford, Bedfordshire, England.

DOUBLING the speed of a lineshaft automatically doubles its capacity for power transmission, and although G.G.K.'s shaft is well loaded at present, it should carry twice as much horsepower when the speed is doubled; that is, so far as the horsepower capacity of the shafting itself is concerned.

The general formula used for the horsepower capacity of shafting is $D^3R \div 75$, and when the bearings are 8 ft. apart, the horsepower may be determined by the formula $D^3R \div 50$, when D equals diameter of shaft and R equals r.p.m.

Safe Capacity of Shafting

Diam. in. Inches	Hp. at 250 r.p.m.	Hp. at 500 r.p.m.
1 1/16	5.58	11.16
1 1/8	9.90	19.80
1 3/16	16.02	32.04
1 1/4	24.24	48.49
2 5/16	34.89	69.78
2 3/8	48.28	96.55
2 7/16	64.70	129.4
2 1/2	84.49	169.0
3 5/16	108.0	215.9
3 3/8	135.4	270.8
3 7/16	167.1	334.3
3 1/2	203.5	407.0
4 3/8	291.3	.....
4 1/2	401.2	.....
5	554.6	.....
6	720.0	.....
6 1/2	915.4	.....
7	1143.0	.....

The data in the accompanying table were taken from the mechanical section of the Standard Handbook for Electrical Engineers, but similar results may be obtained by using the general formula mentioned in the above paragraph. It is evident from this table that doubling the speed of a lineshaft also doubles its horsepower capacity.
E. J. MORRISSEY.
Chief Electrician,
Western United Gas & Electric Co.,
Aurora, Ill.

Operating Generators in Parallel

I have a 400-kw., three-wire, 110/220-volt, compound-wound, General Electric generator which I wish to operate in parallel with a 100-kw., two-wire, 220-volt, Crocker-Wheeler generator. Can these two machines be satisfactorily operated in parallel while the 400-kw., three-wire machine is supplying a three-wire, 110/220-volt load? If not, why not? If so, what scheme of connections must be used and what precautions observed in paralleling them? Can the three-wire machine be operated as a two-wire machine and paralleled with the other two-wire machine? How should I go about paralleling them in this case? Any information that readers may give will be greatly appreciated. J. F.
Dansville, N. Y.

IN ANSWER to J. F.'s question, the machines mentioned can be operated in parallel. When it is desired to operate a three-wire generator in parallel with a two-wire generator, it is necessary to re-connect the series, the commutating, and the compensating fields of the two-wire generator.

These fields of the two-wire generator should be split into two parts. When splitting up the series, the compound and the compensating fields into two sections, one section should be connected to the positive side of the circuit and one section to the negative side. For instance, all the south poles of the series field should be connected in series on one side of the armature and all the north poles in series on the other side. With this arrangement, neglecting the leakage flux, all the poles will be magnetized alike, for if we assume that all load is between the neutral and the line connected to the south series field, then the flux produced by the current flowing in these field coils must flow through the north poles of the generator in completing the circuit.

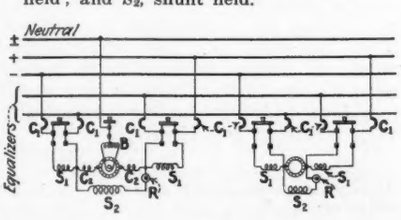
Now, as each of the generators is arranged for two series fields, the machines must be connected to each other, as shown in the accompanying illustration, by two equalizers, although any unbalanced load must be carried by the three-wire machine alone. With the exception of the connections of the three-wire generator, the method of connecting both generators should be the same. It will be noticed, however, that when a three-wire generator is operated in parallel with another generator, two equalizers are needed, whereas only one is needed between two-wire generators.

To provide adequate protection, the circuit breakers must be connected between the machine brushes and the equalizers in order that the tripping elements may be actuated by the full armature current. The two single-pole breakers on the positive and negative leads must be interlocked. Otherwise, should only one breaker open, the compensator or balance coil maintaining the neutral would have to carry the full armature current and would probably be damaged. If placed between the series field and the busbars, the device would be actuated by a current sometimes greater and at other times less than the armature current, depending on the direction in which the equalizer current is being exchanged between the machines. The equalizers are at terminal potential, and unless the voltage is fully built up on the incoming machine before it is paralleled with the running machine, the current in-rush is likely to damage the armature of the incoming machine. For this reason, switching equipments should be such that the series field will be connected in the circuit before the generator is paralleled.

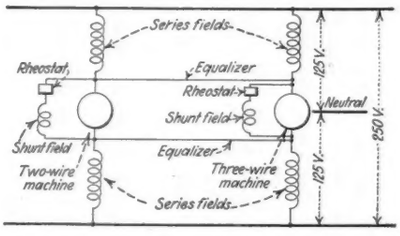
Owing to the fact that unusual care must be exercised when paralleling three-wire, d.c. generators it is advisable that a voltmeter be employed to reduce the likelihood of an accident. When paralleling, as already mentioned, the series field of the incoming machine is connected first; then the two single-pole breakers are closed, one at a time. By connecting a double-reading voltmeter across the last circuit breaker, an indication would be obtained of any unbalanced condition between the two machines; which would make paralleling impossible.
H. J. ACHEE.
District Line Superintendent,
Southwest Light & Power Co.
Elk City, Okla.

This shows how a three-wire and a two-wire generator may be connected in parallel.

In this diagram C_1 represents the circuit breaker; C_2, commutating field; B, balance coil; R, rheostat; S_1, series field; and S_2, shunt field.



ANSWERING J. F.'s question, I would suggest that he refer to a book written by Gandy and Schacht entitled "Direct Current Motor and Generator Troubles," published by the McGraw-Hill Book Co. It is possible to parallel the generators



This shows how a two-wire and a three-wire compound-wound generator can be connected in parallel.

he mentions, providing the series field of the two-wire generator is divided into two parts. One half of this series field should be connected to the positive side and the other half to the negative side of the armature. Two equalizers, however, will be required.

The accompanying illustration shows how these connections should be made. For best results the series field circuits of the generators should be closed at one time, by means of a four-pole switch or circuit breaker on the two-wire machine and a five-pole switch or circuit breaker on the three-wire machine. HORACE TURVILLE.
Lansdale, Pa.

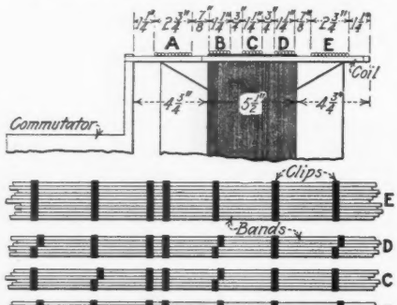
THERE is no reason why J. F. should not be able to parallel his three-wire, 110/220-volt, compound generator with a two-wire, 220-volt generator, provided that the latter is also compound wound. It is advisable, however, to employ two equalizers, connected at a point between the series field and the armature of each unit. The series field of

the two-wire machine should in this case be split into two sections, one half or all north poles being connected on one side and the other half or all south poles on the other side of the armature. The generators can in this way be operated in parallel as though the third wire on the 400-kw. machine did not exist.

FREDERICK KRUG.
Assistant to President,
Porto Rico Railway, Light & Power Co.,
San Juan, Porto Rico.

What Causes Armature to Throw Core Bands?

We are having trouble with the bands on an armature of a 75-kw., 2,400-r.p.m., 230-volt, 200-amp., four-pole, compound-wound turbo-generator. On account of a breakdown the coils were removed from the core, reinsulated, replaced, and connected as before. The winding was then tested with a growler and also a millivolt drop test was made. Next the five steel bands were installed as shown in the diagram. Each band is separate from the others and is thoroughly soldered, with sheet copper reinforcing clips placed at six equi-distant points around the core, except at the start and finish of the band, at which point two copper clips were placed close together. After fitting the bands and again testing the winding,



the armature was replaced and brought up to speed with the field circuit open. The field circuit was then closed and when the generator voltage rose to approximately 100 volts (less than half rated voltage), the bands became so hot that the solder loosened and the bands were thrown off. The air gap was ample, so that the bands were not striking the pole pieces. Furthermore, there was absolutely no indication of heating or other trouble in the winding itself. Will some reader please tell me what causes this armature to throw its bands? Is the trouble caused by having more than four equally spaced sets of copper clips around the periphery or by having two clips together, or both? Any information that readers can given me as to what is causing my trouble will be greatly appreciated.

W. H. E.
Richmond, Va.

REFERRING to W.H.E.'s trouble with the heating of band wires, the kind of banding wire used is very probably the cause of the heating. Band wires are subject to two causes of heating, hysteresis and eddy currents, both of which are due to magnetic effects and not to mechanical friction.

Assume a small length of band wire is located directly beneath a North pole of the magnetic field. While it is in this position the magnetic lines of force pass from the pole face of the field coil across the air gap and into the armature, traversing a path perpendicular to the wire's axis. Now, assume this same portion of band wire moved to a point midway between a North and a South pole face. The magnetic lines in this case become parallel to the band wire. Again move the wire so that it is under a South magnetic pole. The magnetic lines are again vertical to the axis of the wire but they move in the opposite direction to those under the North pole, and in the last part of the cycle the lines are again parallel to the wire. Thus, as each small portion of the band wire is a conductor cutting through a magnetic field, current will be generated in the wire.

The effect on the wire is the same as though it were placed in a field produced by an alternating current. The relative movement of wire and magnetic lines is such as to generate an electromotive force which will cause alternating currents to flow in concentric circles about the axis of the wire. These currents are known as eddy currents and are dissipated as heat. These losses which they cause are proportional to the conductivity of the wire, the square of the frequency, and the square of the flux density of the magnetic field. As the latter two factors have been previously determined for a given machine, the band wire should have a high resistance in order to keep the losses from eddy currents at a minimum.

Referring again to the movement of a small length of the wire through the magnetic field, the flux reverses its direction through the length of wire as the wire passes through the cycle previously described. If the wire contains any magnetic material, this reversal of magnetism causes heating due to hysteresis losses. Hysteresis losses are proportional to the frequency, to the flux density with an exponent of 1.6, and to a coefficient of hysteresis which depends upon the material. This latter factor is the only one affected by the material used for banding wire and should be as low in value as possible. This factor varies considerably for different materials and may be 80 or more times as high for tungsten or manganese steels as for transformer stampings or ordinary iron.

By applying these facts to W.H.E.'s turbo-generator, the heating of the steel band wires is easily accounted for. The frequency of the generator is $(4 \div 2) \times (2{,}400 \div 60) = 80$ cycles, as compared with the frequencies of 10 to 40 ordinarily used in d.c. generator designs. It is also probable that the flux density is high. As the steel band wires are of magnetic material, they would have a very high hysteresis loss and a moderate eddy current loss.

It is suggested that a tinned bronze wire be used for banding W.H.E.'s case. As bronze is an alloy of non-magnetic metals, the hysteresis loss would be negligible. In general, as the tensile strength of bronze is increased by varying its composition, the conductivity decreases at a very much higher rate. A bronze wire of high tensile strength would then have only a small loss from eddy currents and practically none whatever from hysteresis.

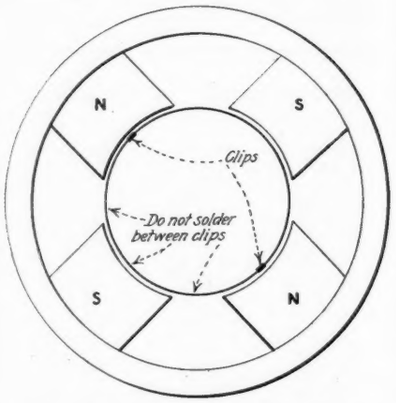
C. W. PEDEN.
Assistant Electrical Engineer.
Aluminum Company of America,
Massena, N. Y.

I WOULD suggest that W.H.E. replace his present core bands with brass ones, but make the width of the bands only one-half that of the former width. The bands should be insulated from the core with either mica or a good grade of insulation, such as horn fiber or fullerboard.

The present trouble is being caused by bands that are too wide and that act as a secondary circuit in the magnetic flux which passes through the air gap. The bands now used cover up too much of the armature core. The writer is quite certain that, if W.H.E. tries the method suggested, he will have no further trouble with the core bands coming off.

AXEL T. SMITH.
Smith Electrical Works,
Sioux City, Iowa.

IN ANSWER to W.H.E., the writer would say that it is a good plan to have no more clips on the core bands than there are pairs of poles. In this case two clips only will be needed and they should be equally spaced. The core bands should be insulated from the core, and no solder



This diagram illustrates where the core bands should be soldered.

should be used on the bands between the clips, as indicated in the accompanying illustration.

Apparently, W. H. E. has by soldering the bands around the core provided a good conductor for the current which is generated in them, this current being sufficient to heat the bands and clips until they loosen.

ALBERT E. CARPENTER.
Shelburne Falls, Mass.

THE trouble experienced by W.H.E. with hot core bands on a 2,400-r.p.m., four-pole armature may be due to any one of several causes. One sure cause of heating is the all-over soldering of the bands. Solder should be applied only at the clips and kept confined to within ¾ in. or so of the clips.

Another sure cause of heating results from the use of more than two clips, for two clips only should be used and spaced equally distant around the armature. Another cause of heating may result from using bands 1¼ in. wide; consequently it might be well to separate each band into two bands,

each being about ⅝ in. wide and so spaced that the bands or clips will not touch each other. In regard to the kind of band wire used, I imagine that the manufacturer of W.H.E.'s armature may have originally used phosphor-bronze band wire, although it is not necessary to do so.

The rebanding of the armature may be accomplished in accordance with the following procedure:

Anchor the end of the band wire to a peg forced between the armature coils at the end of the core. Wind the wire on the core under heavy tension, using thin cut mica under the wire to insulate it from the core. Lay in two ⅝ in. wide, soft, tinned copper clips, spacing them at opposite diameters of the core. Wind the band wires close to each other for a width of ⅝ in., and then bend over the copper clips and solder them, but do not cut the wire, for it should be extended around the armature a few inches beyond the last clip before laying in a clip for the next band. Wind this band in a manner similar to the first one.

One continuous wire can be used to make up all the bands on the core, the ends of the wire terminating at the ends of the core, which are about the coolest places on the armature. The two clips of one band need not be located with reference to the clips of the other bands, the only requirement being that the two clips of one band should be located at opposite diameters of the armature. If good phosphor-bronze wire is used, it should not need tinning, as it will generally take solder readily, but in the event that a flux is needed rosin flux or rosin-core wire solder only should be used. When heavy head bands are used trouble is often experienced with them, if they are soldered all around the armature. Even on these bands two clips only should be used, soldering them at opposite sides of the armature.

Waterbury, Conn. ROBERT B. TREAT.

THE trouble that W.H.E. is having with his band wires is peculiar, in a way, but his difficulty can be easily explained and cured, if my theory is correct.

To start with, by revolving a solid iron or steel core in a magnetic field, eddy currents are set up that tend to heat the core. I have no idea how far this heating effect would go in the way of temperature, but I know that it will generate sufficient heat to destroy insulation on electrical conductors. This was proved by a case that I had, where a melted section of laminations next to a slot caused several breakdowns until the cause was found.

It is only natural to suppose that at least some of the heating in H.W.E.'s bands is caused by eddy currents. As the eddy currents flow they heat the bands until the melting point of the solder is reached, when it softens enough to cause the bands to loosen. The obvious remedy for this trouble is to use band wires made of non-magnetic metals. In this case it may not be desired to use a non-magnetic metal; so the next best remedy is to use only two clips on each band, making the bands as narrow as possible. Solder the bands only at the clips, leaving the wires parallel, but do not solder bands together around the armature between the clips.

This method of remedying W.H.E.'s difficulties offers such few opportunities for the formation of eddy currents that those which are active are practically harmless. Eddy currents are present, of course, at each clip, but the heat generated is carried away so rapidly by the unsoldered wires on each side of the clip that its temperature does not reach the danger point. If this heat were not dissipated weakening of the solder would result and loss of the band would follow. I know by experience that this method works, for after adopting this method in my shops, there have been practically no failures of bands on any armatures. I feel certain that the cause of the core band failures that we have had in the past has been found.

R. R. SCHELLENGER.
Supt. Electrical Department,
Elk Horn Coal Corp.,
Wayland, Ky.

MY SUGGESTIONS in answer to W. H. E.'s question only apply to the bands *B*, *C*, and *D*, in his illustration, and with the understanding that no current was drawn from the armature when trouble was experienced with the core bands.

The core bands were evidently loosened by their heating, which was caused by a combination of hysteresis and eddy current losses. Wide steel bands that protrude slightly above the armature teeth cause the air gap at the bands to be less than it is at the armature teeth, in which case the bands are likely to heat. Bands *B*, *C*, and *D*, are quite wide and should be split into six or seven bands and, if possible, these should be wound directly on the laminations without any insulating mat under them, in the event that it is necessary to use steel wire. The flux of the main field flows the whole distance of a pole pitch through the bands, but if they were down on the teeth of the core the air gap would be greater around the bands and consequently the hysteresis losses would be lessened. Any decrease in the hysteresis losses in the bands caused by the increased air gap, or in any manner, will improve the regulation of the machine.

In a machine of this character with comparatively few slots per pole, fairly thick steel and high densities, I would not anticipate any difficulties from winding steel bands directly on the laminations.

By using a non-magnetic material, such as bronze, for the *B*, *C*, and *D* bands, all the above-mentioned hysteresis losses will be prevented, and regulation will be improved. The area of the bronze wire, if adopted, should be about 2⅔ times that of the steel wire. The bronze bands will have more eddy current heating per unit width than the old bands, but this will be more than offset by the reduction in heating due to the elimination of the hysteresis losses from the bronze bands. The bronze bands seem best adapted for this machine, but the precaution must be taken to make them less than ½ in. in width. The spacing between the bands is immaterial and can be ½ in. or less.

On this particular job I do not believe that the number or position of the clips appreciably influences the loosening of the bands.

Baltimore, Md. GUY K. MITCHELL.

Heating of Fan Motor

I have rewound a 16-inch desk-fan motor, using a coil span of 1-and-3 instead of the former coil span of 1-and-6, and using the same number of turns, coils, and size of wire as formerly used. The motor now operates at a normal speed of 1,750 r.p.m., but becomes abnormally hot within a few minutes after starting. Most of the heat seems to come from the stator iron rather than from the coils themselves. What is the cause of this and how can it be corrected, keeping the present 1-and-3 slot winding? The motor is of the split-phase type, having four poles, 24 slots, and 24 coils with 58 turns of No. 24 single cotton-covered enameled wire per coil. It is rated at 110 volts, 60 cycles. The original winding had a coil span of 1-and-6, 83⅓ per cent pitch. I shall greatly appreciate any information that readers may give me on this problem.

St. Louis, Mo. T. A. B.

IN REPLY to T.A.B.'s question, the first important fact to notice is that reducing the coil pitch has an effect similar to reducing the number of turns per coil, in which case the self-inductance of the coil would be reduced. This effect on the number of turns is not in direct proportion to the percentage of slots dropped, but varies as the sine of one-half the angle in which the coil spans in electrical degrees. Assuming a span of 1-and-6 to be 100 per cent pitch, it follows that with a span of 1-and-3 the cord factor would be approximately 0.64 instead of 1. From this it is evident that the motor is working at about 156 per cent overvoltage.

The heating in T.A.B.'s case is caused by excessive losses, which include both I^2R and iron losses. The former is due to the increase of current used, and the latter is on account of the greater magnetic density of the iron and the increase in eddy currents. If the number of turns per coil is increased to 90 or more, the trouble will be somewhat lessened; however, if the size of wire is reduced to accomplish this, the power of the fan will have to be reduced accordingly. Otherwise, excessive I^2R losses would give trouble again.

In the case of a 16-in. fan motor, it is not feasible to change from a span of 1-and-6 to 1-and-3, if at the same time the original number of poles is to be retained. FRANK HARLE.

Rochester, N. Y.

Data for Building Auto-Transformer

I wish to build an auto-transformer for use on 110-volt, 60-cycle current. This auto-transformer should have a capacity of 15 amp. and should have taps for voltages of 10, 20, 30, 40, 50 and 80 volts. I had planned to use a core made up of iron wire. Will this work satisfactorily? Can some readers give me the correct dimensions of the core that should be used, the size of wire, and the number of turns of wire that will be required? I shall appreciate your help.

Bayonne, N. J. E. J. M.

IN REPLY to E.J.M.'s inquiry, I would strongly advise against the use of iron wire for a core. I am giving below details of a transformer which requires 14.5 lb. of iron, the laminations being about 0.014 in. thick. This iron can be bought, probably cut to size, from almost any manufacturer of transformers or motors, and perhaps from a repair shop. Starting with the core, proceed with the construction of the transformer as follows:

Cut enough laminations, 1.5 in. x 5.625 in. for two cores, allowing 4.62 lb. per core. This iron should be stacked between two templets spaced 7⅛ in. apart, butting the individual laminations alternately against the templets. When stacking is completed, the core iron should be drawn together in a C-clamp, or vise, and then wound with friction tape over the solid portion, which should measure 2.25 in. in thickness. The yoke iron (top and bottom) is cut 1.5 in. x 3.125 in., the total weight being 5.2 lb. These laminations are inserted in the spaces provided for them in the cores, after the coils have been wound on the cores. The solid portion of the cores will measure 4.125 in. in length. The insulation around the cores, and also between the layers, should be cut 4 in. wide, which leaves ⅛ in. for pressboard under the top and bottom yokes. Insulation should be provided as follows: Around the core use 0.05-in. paper or fullerboard, and between the layers 0.01-in. paper or empire cloth.

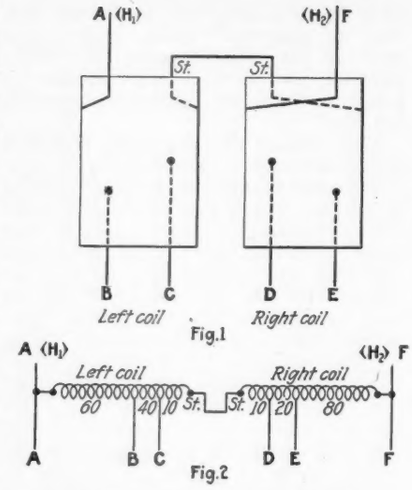
Two coils are required, one for each core. Each coil is wound on an insulated core with 110 turns of No. 10 square B & S gage d.c.c. wire, as follows: The first three layers are wound with 28 turns per layer; the fourth layer contains 26 turns. The winding occupies 3.5 in. on each layer, leaving a ½-in. space at each end. About 183 ft., or 7 lb., of wire is required. Both coils must be wound in the same direction, as shown in Fig. 1 in the accompanying illustration.

Taps are taken from the left-hand coil at the 10th and 50th turns from the start, and from the right-hand coil at the 10th and 30th turns from the start of the winding. For taps, strap copper ½ in. wide should be doubled around and soldered to the wire. The taps should be carefully insulated with paper or empire cloth from the rest of the layer in which they are connected. All leads and taps should be wound with cotton tape to the point of connection with the coil. The two start leads, *St.* in Fig. 1, must be permanently connected together when the transformer is completed. The last layer on each coil should be covered with cotton tape.

The two coils, or legs, are then placed side by side and the laminations for the top and bottom yokes inserted around the coil. The entire transformer may now be impregnated, if desired.

With 110 volts impressed across H_1 and H_2, the following voltages may be obtained:

Volts	Leads	Volts	Leads
10	C-D	50	A-C
20	C-E	60	A-D
30	B-D	70	A-E
40	B-E	80	B-F



This shows the construction of a 15-amp., 110-volt auto-transformer which is tapped for 10, 20, 30, 40, 50, and 80 volts.

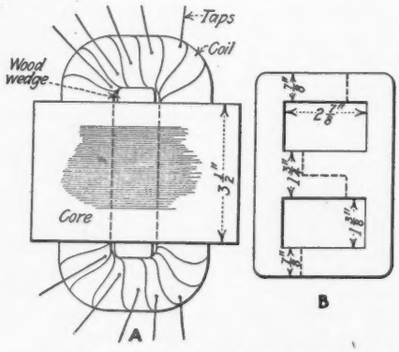
The iron loss will be from 10 to 20 watts, depending on the quality of the iron. The I^2R loss will be about 10 watts when the connected ratio is 110 to 50 volts, and the transformer is delivering 15 amp. This gives an efficiency of about 97 per cent, and the no-load current will be about 0.7 amp.

The No. 12 s.c.c. or d.c.c. wires in parallel, wound simultaneously side by side, may be substituted if No. 10 wire is not available. This will require an extra layer and a half, keeping the same number of turns, 110 turns per coil; so taps must be soldered to both wires in this case. Fig. 2 in the illustration shows the development of the winding, and the number of turns between the various leads and taps. Leads H_1 and H_2 should be connected to *A* and *F* respectively, when permanent connections are made to the 110-volt line.

St. Louis, Mo. T. A. BRENNER.

IN ANSWER to E.J.M., the writer has made auto-transformers similar to the one he has in mind. The coil of those I made were wound with a total of 230 turns of No. 12 wire and was designed for continuous duty at 220 volts. As each turn makes a difference of 1 volt, E.J.M. can arrange the taps on his coil to suit his requirements. It will be necessary to take the taps off the coil at the ends only, as indicated in the accompanying illustration at *A*. The core is made of 3½-in. iron shaped as shown at *B*. ALBERT E. CARPENTER.

Shelburne Falls, Mass.



This auto-transformer was designed for continuous service on 220 volts.

Size of Alternator Required for Industrial Plant

We wish information on selecting capacity of alternators for small a.c. power plants for industrial use. (1) Recently we had to calculate the size of generator required to drive two 175-hp., 80 per cent power factor, three-phase, 60-cycle, 257-r.p.m., 440-volt, synchronous motors direct-connected to ammonia compressors, and three or four small, squirrel-cage induction motors aggregating 60 hp. The generator was required to be able to start one synchronous motor at full line voltage when the other synchronous motor was already developing full capacity. What generator capacity would be required to handle this load?

(2) Another recent case involved the electrification of a small factory. There were about ten 5-hp. motors, four 10-hp. motors and two 25-hp. motors, all squirrel-cage induction motors; the lighting load was about 5 kw. and there was one passenger elevator requiring one 7½-hp. motor. It was desired to have the three-phase, 60-cycle, 220-volt generator direct-connected to a crude oil engine. What capacity of generator would be required in this case? In arriving at the size of generator required, is it enough to add the various full-load currents of the motors and use this as the size of the generator? How do we take into consideration the power factor and the inrush current taken by the motors in starting? How can we be sure that the voltage will not drop very much so as to cause flickering in the lights when the motors are started, especially when the elevator is operating? A. B.

Lima, Peru.

REPLYING to the question by A. B., I would say that usually the problem of insuring adequate capacity in small industrial installations is not so much a question of generator size as it is of having a prime mover of the proper size for the conditions.

It is inherently difficult in small installations to eliminate voltage fluctuations and speed variations entirely when a large motor is started up, so the size of the prime mover and the generator is generally such that enough excess capacity is available to allow only a little disturbance under the worst operating conditions.

(1) Assuming that the synchronous motors could be excited for a leading power factor, it will be found that they have more than enough capacity to make up for the lagging power factor of the induction motors so that the generator could be run at unity power factor. Then, as there is a total load of $(175 \times 2) + 60 = 410$ hp. or 306 kw., a 300-kva. alternator would be adequate for ordinary running conditions, since all motors would probably not be loaded up to capacity. The additional capacity required to provide for starting the second synchronous motor when one is in service together with the other motors can no doubt be neglected, since a synchronous motor cannot be started under heavy load, and the starting current required by this motor will not much exceed the full-load current with properly designed starting equipment. The most certain way of settling this point is to obtain the characteristic curves of the synchronous motors and the generator

from the manufacturer who is to supply them.

(2) In this case there are no synchronous motors to correct power factor and the generator must have sufficient capacity to take care of the lagging current due to the induction motors. Now, the power factor of the induction motors when operating will depend on a number of factors the principal ones being the speed and the load on the motors. Assuming that the motors have been selected with as high a speed as the drives will permit, and that their size is such that they are fully loaded, a power factor of at least 80 per cent, should be obtained. The power load should be $(5 \times 10) + (10 \times 4) + (25 \times 2) + (7.5 \times 1) = 147.5$ hp. or 110 kw.

With a power factor of 80 per cent the theoretical generator size would be $110 \div 0.8 = 137.5$ kva. After adding to this figure 5 kva., which represents the lighting load (as this load is non-inductive, kw. = kva.), there will be a total of 142.5 kva., and the nearest available commercial generator size will probably be found to be 150 kva. A generator of this size will be fully capable of handling any momentary overload incident to starting up the last motor when the others are in service.

To keep the disturbance of lighting at a minimum, the generator should be provided with a quick-acting, automatic voltage regulator, and the prime mover with a sensitive governor. Upon these two devices, more than anything else, will depend the smoothness of operation.

FREDERICK KRUG.
Superintendent of Power Production, Porto Rico Railway, Light & Power Co., San Juan, Porto Rico.

Changing Speed of Induction Motor

I have a 10-hp., 1,200 r.p.m., 220-volt, three-phase, 60-cycle, Westinghouse squirrel-cage induction motor that has 54 slots and 54 coils having a span of 1-and-8. Each coil is composed of 15 turns of two No. 16 d.c.c. wires in parallel. The winding is six-pole and is connected two-circuit star. I wish to reconnect this winding so as to have the motor develop 10 hp. at 1,800 r.p.m., when used on the same supply as before. Can some of the readers tell me how to reconnect the motor to obtain this result?
Chicago, Ill. C. R.

IN REPLY to the question by C.R., I would suggest rewinding this motor as the most satisfactory means of obtaining the best results, but if C.R. does not care to spend the money for rewinding, the motor can be reconnected with the present coils.

As the span is only 1-and-8, the starting torque, when connected four-pole for 1,800 r.p.m. will be reduced considerably, and the motor may fail to start its former load; however, by killing 6 coils and 48 coils, which means 12 coils to a pole instead of the full 54 coils with 9 coils per pole for 1,200-r.p.m. operation, the motor will operate.

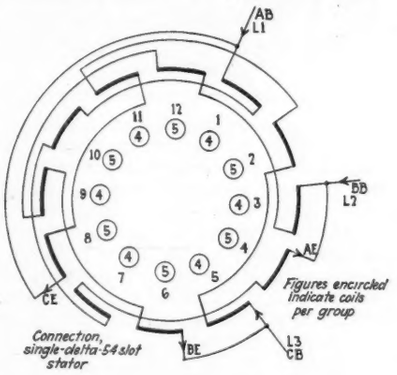
The original two-star connection should be changed to single delta to take care of the increase in the number of turns in series caused by the regrouping.

If the motor is rewound and reconnected entirely, it will develop approximately 15 hp. at 1,800 r.p.m., but if it is reconnected as I have suggested, I doubt if more than the 10 hp. will be developed.

LEE F. DANN.
Donnacona, Que., Can.

REPLYING to the question by C.R., the motor can be reconnected for 1,800 r.p.m., at the same voltage and approximately 15 hp.

A change in speed is equivalent to a change in voltage; so the windings must be changed accordingly. The two definite limits to the speed in this case are mentioned in a book entitled "Alternating Current Armature Winding,"



This diagram shows the connections of a three-phase induction motor for changing the speed from 1,200 to 1,800 r.p.m.

by Terrell Croft, in which it is stated in section 150 that, (1) the speed (peripheral speed) of the rotor, should not exceed 7,000 f.p.m. (2) The pitch factor should not be greater than 1.5 or smaller than 0.5.

When the motor coils are not divisible by the number of poles or groups, usually an unequal grouping can be arranged, and in this case that would be necessary. For example, $54 \div 12 = 4\frac{1}{2}$; so it will be necessary to distribute the remaining six coils equally around the stator. In this case every other group would have five coils, and the grouping would be as follows: 4, 5, 4, 5, 4, 5, 4, 5, 4, 5, 4, 5. This arrangement will give 18 coils per phase in a well-distributed winding.

The connection of the stator winding should be changed to single delta, which would be the proper connection for approximately 205 volts. Although the 220-volt line will cause the windings to operate at 7 per cent overvoltage, this voltage is near enough for practical purposes. The accompanying illustration shows how the coils should be connected and the number of coils per group.

GRADY H. EMERSON.
Birmingham, Ala.

REGARDING C.R.'s question, the six-pole, 10-hp. motor can be reconnected two-parallel star for four poles, 220 volts and 11 hp., using 12 groups of four and five coils per group, as, 4-4-4, 5-5-5, 4-4-4, 5-5-5. This reconnection can be worked out as follows:

The change desired is from six to four poles, or from 1,200 to 1,800 r.p.m. As an increase in speed affects the voltage and horsepower in direct proportion to the speed increase, the new line voltage should be $220 \times (18 \div 12) = 1.5 \times 220 = 330$ volts. Then the new rating will be $1.5 \times 10 = 15$ hp.

The above does not take into consideration the chord factor for both windings. For the six-pole winding the pitch is 1-and-8, which is chorded two slots as full pitch equals $54 \div 6 = 9$, or 1-and-10. Now the chord factor for the six-pole winding can be worked out as follows: 180 deg. $\div$ 9 = 20 deg., $20 \times 7 = 140$ deg., $140 \div 2 = 70$, and the sine of 70 deg. = 0.93969.

As this same winding is to be reconnected for four poles, the chord factor for the same winding, grouped for four poles, will be less than given above. It can be worked out thus:

Full pitch for 54 slots and 4 poles $= 54 \div 4 = 13.5$, or 1-and-14.5. The electrical angle between slots $= 180 \div 13.5 = 13.3$ deg. Then with the 1-and-8 pitch the electrical angle between the coil sides equals $13.3 \times 7 = 93.31$. Half this angle equals $93.31 \div 2 = 46.655$ deg. or 46 deg. 39 min. The sine of this angle is 0.72717.

If the six-pole winding had been full pitch and connected series-star, the voltage would have been $(2 \times 220) \div 0.93969 = 468$ volts. Then the four-pole, full pitch, series-star line voltage would have been $468 \times 1.5 = 702$ volts. But, as the pitch of the proposed four-pole winding is 1-and-8 and its chord factor is 0.72717, the four-pole series-star line voltage will be $702 \times 0.72717 = 510.5$ volts, or 510 volts in round numbers.

Now, if we reconnect the four-pole winding two-parallel star, the line voltage will have to be $510 \div 2 = 255$ volts. Then as the service voltage obtainable is only 220 volts, we will lose some of the horsepower rating. As the horsepower is directly proportional to the speed and torque and as the torque varies as the square of the voltage, the final rating will be lower, as $220 \div 255 = 0.8627$, or the four-pole winding voltage is 13.73 per cent too high. Then if we operate the four-pole winding on 220 volts, the torque will represent a reduction in full-load torque amounting to $(220)^2 \div (255)^2 = 48{,}400 \div 65{,}025 = 0.7443$, or 74.43 per cent.

With the speed remaining constant, the horsepower will vary directly with the torque. Consequently, the horsepower at 1,800 r.p.m., 220 volts, and with the 1-and-8 pitch will be $15 \times 0.7443 = 11.165$, or 11 horsepower. In this case, reducing the required line voltage of 255 to the service line voltage of 220 made a reduction of 13.73 per cent in voltage and a 25.57 per cent reduction in torque and horsepower.

Therefore, the present winding, if regrouped for four poles with 12 groups and connected two-parallel star, will be good for operation at 220 volts, three phase, 1,800 r.p.m. and will develop 10 or 11 hp.

The starting and pull-out torques will be higher, due to the increased rotor resistance, the iron below the slots should be sufficient, and the motor should operate satisfactorily.

A. C. ROE.
Renewal Parts Engineering Dept., Westinghouse Electric & Manufacturing Co., Homewood, Pa.

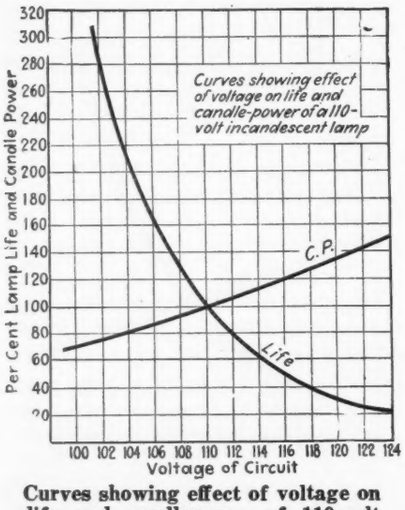
Electrical Service

AROUND THE WORKS

For this section short articles describing ideas and practical methods devised to meet particular operating conditions are invited from readers. The items may refer to inspection, overhauling, testing, and emergency or special installations.

Using Voltage Records to Select Proper Lamps

PRIOR to the installation of a graphic voltmeter, a plant in the industrial district of a large city was buying 110-volt lamps and getting about 50 per cent of the rated life. The lighting and power were supplied from the same feeder, but with separate transformers. However, during the day, when all the plants of the district were operating, the lighting voltage averaged 115 volts, but during the night it ran as high as 130 volts. As a result, they are now buying 115-volt lamps for all circuits except those used at night, on which 125-volt lamps are used.



Curves showing effect of voltage on life and candlepower of 110-volt incandescent lamp.

In order to determine lamp life and candlepower of 110-volt lamps at other than rated voltage, trace upward from voltage of circuit, intersecting curves. From these points of intersection, trace left to column, per cent lamp life and candlepower. For instance, 100 per cent lamp life of 110-volt lamps is shown at intersection of curves.

All this tends to substantiate the importance of the present-day incandescent lighting problem, of which cost of electricity and cost of lamps are the two most important elements. An incandescent lamp consumes its rated wattage, gives its rated candlepower and lasts its rated life only when supplied with its rated voltage. If the voltage supplied to the lamp is less than the rated lamp voltage, the candlepower and the wattage consumption are decreased and the lamp life is lengthened.

If the voltage supplied is greater than the rated lamp voltage, the candlepower and the wattage consumption are increased and the lamp life is shortened.

The balance between lamp life, light obtained and energy consumed, all of which vary with the voltage, is a rather delicate one to maintain, since the candlepower varies directly as the 3.5 power, and the life of the lamp inversely as the 13.5 power of the voltage. It is apparent, therefore, that a voltage too low for the lamp greatly reduces the amount of light obtained, and a voltage too high greatly shortens the life and increases the cost of the lamps.

In order to show what this means, the Esterline-Angus Co., Indianapolis, Ind., has computed, from data supplied by the National Electric Lamp Association, the curves of life and candlepower of 110-volt lamps when burned on circuit voltages of from 100 to 125 volts.

These curves show the necessity of knowing accurately the voltage in buying lamps, and of maintaining voltages for which lamps have been supplied. For example, a 110-volt lamp supplied at 112 volts suffers a reduction in life of 21 per cent and of 38 per cent if supplied at 114 volts.

Since the light given and the watts consumed increase with the voltage, while the lamp life is decreased, there is, depending upon the price of lamps and the price of a kilowatt-hour of energy, a relation between circuit voltage and lamp voltage rating, which will give the minimum cost of light.

Therefore, in order to buy and use incandescent lamps intelligently and economically, the voltage at which they are to be used must be accurately known. Every consumer of consequence will find it profitable to use a reliable recording voltmeter, and buy lamps of the proper voltage rating, as determined from the records of the instrument.

Simple Control to Stop Motor When Conveyor Clogs

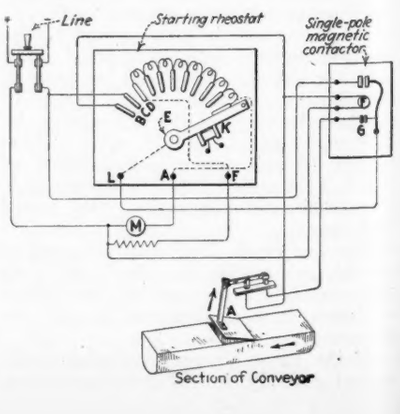
THE control system for conveyor motors shown in the illustration is in service in an Iowa plaster mill and has eliminated considerable trouble since it was installed. An explanation of the conditions under which this device operates will help the reader to understand its purpose.

A screw conveyor about 120 ft. long is used to move plaster from one building to another, the conveyor screw being 12 in. in diameter. Occasionally the bin at the discharge end of the conveyor would become filled up and cause the conveyor to stall. If the attendant was busy somewhere else at the time, either a belt or the paper pulley on the motor would be destroyed. It was finally decided to install some device to shut down the motor when the conveyor became clogged up. For this purpose, a 16-in. section of the conveyor was arranged as a hinged door opening upward. This door is shown at *A* in the illustration. It was connected to a single-pole, inclosed switch which opens when the material being handled clogs and presses against the hinged door hard enough to lift it up.

The original arrangement of the starting rheostat was changed somewhat, as shown at *B* and *C*. The resistance coil formerly connected between contacts *C* and *D*, and the spring *E* for returning the starting handle to the "off" position were removed. A single-pole magnetic contactor and the necessary wiring completed the job at a very small cost.

Assuming that the motor is idle and ready to be started, it is first necessary to bring the rheostat handle to the "off" position, thus bridging contacts *B* and *C*. This will close the circuit through the coil *F* of the contactor. The handle of the rheostat can now be moved forward to start the motor, as the contact maintaining stud *G* will keep the contactor in a closed position, if switch *A* is closed, although contacts *B* and *C* are no longer bridged. If the conveyor clogs the hinged door is pushed up, opening switch *A*, and thus breaking the circuit to contactor coil *F*.

The pressure of the material in the conveyor raises the hinged door, opening switch A, which, in turn, causes the contactor to open the motor circuit.



The contactor in turn opens the motor circuit and stops the conveyor.

In order to start again after clearing up the conveyor trouble and closing the switch at *A*, the rheostat handle must again be brought to the "off" position at *B* and *C* in order to start the motor. The low-voltage release coil, *K*, is not used, but voltage failure will cause the contactor to open, which, in turn, stops the motor.

The idea involved in this control arrangement can no doubt be modified to suit other industrial applications.

Electrician, CHAS. A. PETERSON.
Fairbanks Exploration Co.,
Fairbanks, Alaska.

Operating Features of Automatic Charging Station for Storage Battery Trucks

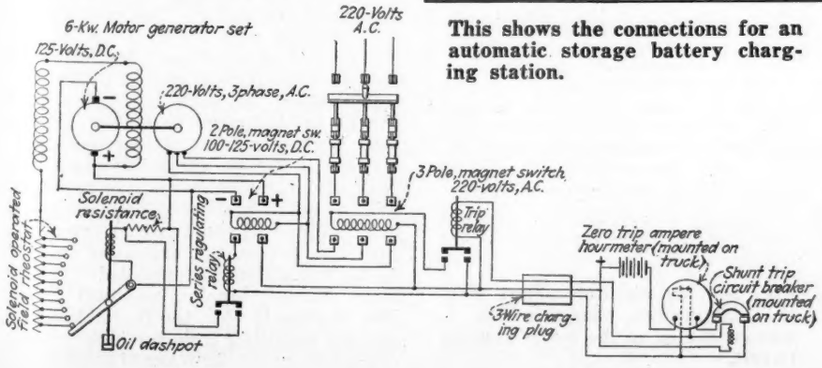
HERE are the details of an automatic battery charging station designed to meet the needs of a small manufacturer using one electric truck. It was designed to take power from a 220-volt, three-phase alternating-current circuit and to perform the following functions: First, it must start automatically when the truck driver connects the battery to the charging panel; second, it must maintain a constant current rate throughout the period of the charge, as the battery was of the nickel-iron, alkaline type; third, it must disconnect the battery in case of power failure and continue charging upon return of same; fourth, it must disconnect the battery at the completion of the charge and shut down the motor-generator set.

A 6-kw. motor-generator set was used. The normal charging rate of 38 amp. was obtained by the use of a series regulating relay and a solenoid operated field rheostat, as shown in the accompanying illustration. The series regulating relay is wound to drop its core at a current of less than 38 amp. The resistance placed in the solenoid circuit is proportioned to allow just enough current to flow to hold the core stationary. Whenever the current rate drops below normal, the series regulating relay drops its core, lowering the resistance and causes the solenoid core to rise at any predetermined speed (obtained by adjusting the oil dashpot), cutting out some of the field resistance and raising the generator voltage and charging current. When the current rate reaches the normal value, 38 amp., the relay operates, cutting in the resistance and causing the solenoid to remain stationary until further regulation of the charging is required. In operation the driver connects the battery to the charging panel by inserting the charging plug into the receptacle on the truck and pushing in the shunt trip circuit breaker. This energizes the three-pole, 220-volt a.c. magnet switch which connects the alternating-current motor to the line, and also energizes the two-pole, 100/125-volt d.c. magnet switch which connects the battery to the shunt generator. The additional torque produced by the motorized generator reduces the a.c. starting current to a value slightly above full load rating.

Again, the value of the generator field resistance is so proportioned that when the normal speed is obtained, the voltage, with all the field resistance cut in, will equal that of the battery. After the motor generator set has reached normal speed, the series regulating relay operates as outlined above, maintaining a constant current rate of 38 amp. When the ampere-hour meter indicates full charge, the zero contacts close, tripping the shunt trip circuit breaker and the trip relay, which disconnects the battery from the panel and shuts down the motor-generator set.

A station of this kind, if carefully built, will give faithful and continuous service for a long period of time. The only attention needed is an occasional inspection of contacts and working parts and oiling the motor generator set. The slightly higher first cost of construction will be overbalanced by the better operating efficiency of the battery and the elimination of an attendant while charging.

St. Louis, Mo. D. F. O'DONNELL.

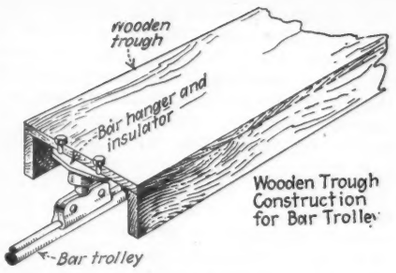


This shows the connections for an automatic storage battery charging station.

Method of Supporting Trolley Wire for Monorail Crane

A TROLLEY wire, in order to allow the wheel to ride true, must make as true an arc as possible around curves. This requires that the ears or some other method of support be spaced close together at curves and, where sharp bends are present, I would suggest that the use of trolley wire at the bends be dispensed with entirely.

It has been my experience, in such cases, that the wire becomes pitted from excessive arcing due to the wheel snapping around the bends from ear to ear. Naturally, such a condition does not do the wire or the motor any good and presents causes for production hold-ups and extra maintenance or repair work.



This bar trolley prevents the trolley from jumping and sparking at the curves.

Experience, the greatest teacher of all, reminds me to suggest the use of a bar trolley, which should be made of a suitable size and cross-section, at least equivalent in current-carrying capacity to the remaining trolley wire, and bent to the desired radius to allow the wheel to ride around the curve gradually and without any snap.

This trolley can be made up of iron bar approximately $\frac{5}{8}$ in. thick by $1\frac{1}{4}$ in. wide and of a length sufficient to extend around the curve. Improvised insulated hangers can be used for suspending the wire, but I would suggest that regular trough-type hangers be used and that the bars be suspended under a wooden trough, as indicated in the accompanying illustration. This trough can be rigidly suspended or fastened, as local conditions would determine such a procedure.

In addition to the trough serving as a support for the trolley bar, it also protects the bar from the top, and the sides of the trough retain the trolley pole in case it should leave the trolley bar for any reason while making the curve.

NATHANIEL W. BLANCHARD.
Inwood, L. I.

Damaged Feeders Replaced Without Interruption to Production

AS THE result of a fire it was necessary for us to replace six three-phase, three-wire circuits consisting of two 350,000-circ.mil cables in parallel. Each circuit was approximately 150 ft. in length and installed in 3-in. conduits using 12 ducts in all. Our first move was to cut out one-half of each damaged and grounded circuit since they were carrying a light load. This made cutting possible.

We next set up a motor-driven hoist which had a 25-hp. motor on it for the purpose of pulling these cables, which were melted down and stuck inside of the conduit. Imagine our surprise when we broke a $\frac{1}{2}$-in. steel cable four times without moving the first feeder. This was finally overcome by anchoring the conduit with $\frac{1}{2}$-in. bolts and collars ahead of the couplings to the building beams, after which we put a heavy tension on the feeder with the hoist. We then attached a $\frac{1}{2}$-ton chain block to the cable for a steady pull.

In this manner we were able to move the feeder, after which it was easy for the hoist to pull the cables out of the conduits. We attached to the far

end of the feeder a ¾-in. manila rope to pull in the new cable, but as the wire came out the insulation was stripped off. This insulation completely choked the duct. Until this insulation was removed from the conduit we knew it would be impossible to pull in the new wire.

Compressed air was used without any result, so after many schemes were considered we decided to try to melt this collection at a low place where the conduits dipped down to pass under an obstruction. This was the solution to our dilemma, although in a very unexpected way. The low place in the conduit was heated to a cherry red with an acetylene torch and compressed air at 60-lb. pressure was blown in at the end of the duct. The insulation immediately took fire and burned with a fierceness that was startling. Flame came out of the ducts like a gas main on fire, but did not cause any damage, as we were in a fireproof building. This cleaned the ducts but burned up the rope, making it necessary to fish these ducts again, which was done with a regular tape line pulling in ¾-in. steel cable.

As it was necessary to keep production moving we were careful not to disturb the other circuits, which were also badly charred but still working. One complete feeder was then cut to the right length, pulled into the ducts and finally cut into service. The three other wires of this circuit were cut out on Sunday. In this way we managed to keep production up to 100 per cent and at the same time obtained a chance to replace another circuit during the week, which was cut in the following Sunday. This operation was repeated each week until the job was completed. One of these temporary feeders was made up of old wire, so that only the actual amount of wire needed was purchased for replacement. I also want to state that two ducts failed to respond to our efforts and finally were cut in two and then burned out. The total amount of 350,000 circular mil cable used was 4,985 feet, requiring the services of from 2 to 10 men as needed, the actual time charged against this job being 432 man hours. This is, I believe, the worst repair job that I ever experienced.

LEO E. BENEZE.
Alton, Illinois.

Simple Limit Switch to Prevent Overtravel of Hoist

A HOIST to dump cars was recently equipped with an automatic limit switch to prevent careless operators from allowing the hoist to go beyond safe limits. This hoist is driven by a 25-hp., 440-volt, three-phase, Westinghouse slip-ring motor, which is geared 10 to 1 to the 10-in. cable drum.

A piece of cold-rolled steel threaded on a lathe was screwed in a hole, drilled in the end of the drum shaft, and tapped for a U.S. standard ¾-in. bolt, as indicated at *G*, in Fig. 1. A traveler, *C*, was made to operate on the threaded rod, *F*, when the drum revolves. This traveler moves away from the drum when it revolves in one direction, and toward the drum when it revolves in the other direction.

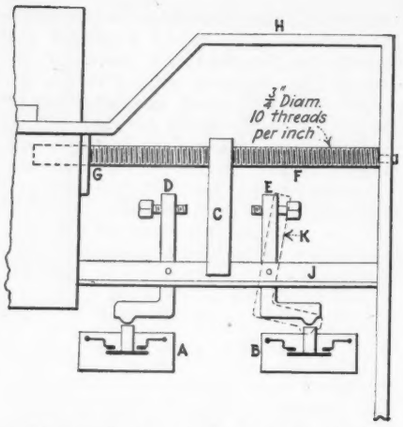


Fig. 1—This switch is used to limit the travel of a hoist by opening a contactor.

The limit stops *D* and *E* cause the contactor *L*, in Fig. 2, to trip whenever the drum travels too far in either direction. The setscrews shown at *D* and *E* are for the purpose of closely adjusting the limit of travel of the drum. General Electric type CR2940 BS211A push buttons are used at *A* and *B*, Fig. 1. During the normal operation of the hoist, these buttons are closed. A piece of light angle iron *J* was used to keep the traveler in a perpendicular position by means of a slot cut in the lower end of *C* sliding over one side of the angle iron. The dotted line *K* indicates the position of *E* when the button *B* causes the contactor *L* to trip.

In order to start the hoist after the automatic limit switch has tripped, it is first necessary to put the controller handle in the off position, to close the control circuit through the reset contact. This closes the circuit up to switch *M*. By closing the top contact of switch *M*, the two-pole, 60-amp., 440-volt Cutler-Hammer contactor *L*, Fig. 2, is made to close, if switches *A* and *B* are closed. But if switch *A* is open, switch A_1 must be closed and the motor started by moving the controller handle. When the traveler *C*, in Fig. 1, has moved far enough to allow switch *A* to close, then switch A_1 and the top contact of switch *M* can be released. Likewise B_1 allows the operator to close the contactor after it has been opened by overtravel in the opposite direction, which results in *B* opening the control circuit.

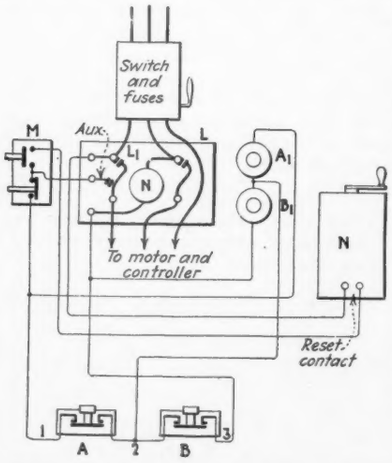


Fig. 2—This diagram shows how the limit switch, shown in Fig. 1, was connected to the motor control circuit.

Whenever switches *A* and *B* have opened, the starting procedure just described must be followed out. Of course, when switches *A* and *B* are closed and contactor *L* is open, it will only be necessary to put the control handle in the off position and close the upper contact of switch *M;* then the contactor will remain in the closed position without continuing to keep the upper contact of switch *M* closed.

Electrician, CHAS. A. PETERSON.
Fairbanks Exploration Co.,
Fairbanks, Alaska.

Protection of Separately Excited Generators Against Power Failure

A LARGE manufacturer of nickel-iron storage batteries has to employ several motor-generator sets used for charging and discharging new storage cells. It is necessary to do such boosting in order to take up the increasing back pressure from the cells as they become charged, meanwhile maintaining a constant rate of charge, which is much desired for this type of cell.

To simplify operation, the generator field coils were separately excited by being connected to the same source of direct current as the motor. These were protected by undervoltage and overvoltage circuit breakers. The charging line through the generator armature was protected by a modern type of reverse current breaker.

It would seem, then, that all necessary precautions had been taken against mishaps, subject, of course, to the testing out of the breakers, as was done frequently. However, when the power failed one morning, enough current backed up through the generator armature with the weak residual field to cause it to operate as a series motor running without load. The result was that in a few seconds the motor attained such speed that the armatures of both the motor and generator flew apart and were utterly ruined.

It will be noticed that for practical purposes the motor was doubly protected against power failure, for either breaker would take care of the loss or abrupt restoration of power, and so should one fail to function the other one would be awaiting its opportunity to protect the motor. The reverse current breaker was found to be in perfect operating condition. Its failure to operate properly was caused by the batteries being in such a condition of charge or discharge that they did not send back a current strong enough to operate it before excessive speed was reached. The machine is now protected with a centrifugal speed-regulating cutout designed to short-circuit the armature line across the armature as soon as the rated speed is exceeded. The reverse current breaker was left in the line to open it with the probable heavy current resulting from the short-circuit.

Orange, N. J. EDWARD MASTERSON.

MECHANICAL MAINTENANCE OF *Power Drives*

This department will furnish mechanical details of installation, operation and maintenance of equipment in the path of power service from the first mechanical driving element through the auxiliary transmitting equipment to all driven machines.

Use of Ball Bearings on Heavy Grinding Machine

GRINDING of heavy steel machine castings subjects the bearing of grinders and their driving motors to unusually severe service. The problem of reducing bearing maintenance costs was attacked about 10 yr. ago when conversions and new installations brought the first ball bearings into service in this plant. Their dust-proof housings affected a marked reduction in maintenance costs.

The castings handled are of manganese and other steels, all for heavy machinery. Grinding operations involve the use of several types of special grinding heads designed by our company, as well as stationary and swinging grinding wheels of standard form. The unavoidable abrasive action of emery and metal dust, the heavy loads imposed, and the thrust loads encountered on the grinding heads all combined to make the type of sleeve bearings which we had been using a source of many shutdowns and considerable expense. SKF ball bearings were installed to overcome this trouble.

These bearings are well adapted to our severe working conditions and are now used extensively throughout the plant. Thirty-six grinding wheels are driven by d.c. motors, direct-connected to the wheel shafts by flexible couplings. All of these motors are equipped with these bearings. The accompanying table gives their ratings and speeds.

Number of Motors	Horsepower Rating	Type and Speeds (r.p.m.)
23	2.5	Variable 1,200/2,600
9	5	Variable 600/1,400
3	15	Constant 1,700
1	20	Constant 1,400

Also, these ball bearings are used exclusively on all special grinding heads, on many of the stationary and swinging wheel shafts, and on lineshaft drives for machine tools and freight elevators.

The types of bearings most widely used are the radial, both deep-groove and self-aligning, and the standard thrust bearing. Some of the new equipment has come standard with these bearings but a considerable number of machines have been converted to ball bearings, after previous operation with ordinary bearings.

The major advantage which we have found to result from the use of ball bearings under the prevailing operating conditions is lower maintenance cost as compared with the ordinary bearings. Ball bearings do not wear the shafting as do the ordinary bearings when they cause trouble and this has made an appreciable saving. With less maintenance and fewer bearing renewals, there are fewer delays and correspondingly increased production throughout the plant.

Another important point is that bearing renewals can be made quickly. Less oiling and inspection labor is required with ball bearings, and the cost of the lubricant required is lower. There is also a saving in power. Equipping with ball bearings motors that drive grinding wheels has reduced bearing repair costs by at least 50 per cent.

One of the outstanding cases in which the ball bearing have proved particularly valuable is on a 30-in. x 96-in. grinder. Due to the thrust load on the grinding head the old bearings, which were considered of high quality, wore rapidly, and had to be renewed frequently, causing considerable expense and serious delays. This machine is used for grinding manganese wheels, pump parts and miscellaneous rollers, and is in operation for an average of 10 hr. per day.

This problem was eventually submitted to the ball-bearing manufacturers and a plan offered to adapt the machine for ball bearings. Although some engineers claimed that ball bearings would not be satisfactory on this application, there have been no signs of trouble after more than 2 yr. of continuous operation. The bearings are in good condition and have required no attention whatever except for the regular oiling. As a result of our experience on the grinding head of this machine a 16-in. x 60-in. grinder has recently been rebuilt in the same way.

Some of the savings effected by employing ball-bearing-equipped motors to drive the grinding wheels are as follows: The saving in oiling and inspection labor amounts to $196 annually, which is a reduction of 65 per cent. Formerly the bearings had to be oiled and inspected every day, whereas now they are inspected once a week, and in many cases no new grease is added to the cups for a period of at least several months.

For the 36 grinding wheel motors so equipped, the saving in the actual cost of the lubricant amounts to $32.52 per year, a reduction of 72 per cent in this item. The saving on these two items alone is $228.52. What is still more important is the 50 per cent reduction in bearing repair costs. This is difficult to evaluate in dollars and cents because repair charges are variable, but it is estimated that this item alone amounts to between $400 and $500 a year.

Still more striking are the savings effected by equipping the 30-in. x 96-in. grinder with ball bearings. The former bearings had to be renewed after an average of one year of service and the annual replacement cost, including labor and material, amounted to at least $353.

The annual fixed charges on the cost of adapting the grinder for ball bearings amount to $79.80, but the cost of renewing the ball bearings hereafter will be no more than $60 including labor. Since the ball bearings have been in service 2 yr. and are still in good condition, it is conservative to assume the average life as 2 yr. and so make the annual replacement cost $30. Adding the fixed charges, the present annual saving effected is $243.20 in repair costs alone.

In addition, there is a saving in machine time, valued at $1.50 an hour, exclusive of the operator's wage. When the old bearings were replaced an average of 48 hr. of regular machine time was lost yearly, whereas the ball bearings can now be renewed with no more than 16 hr. lost time in a 2 yr. period. This is a net annual saving in machine time of 40 hr., which is equivalent to $60. We estimate that the total saving on the 30-in. x 96-in. grinder is $303.20 annually, or about one-half of the original cost of the changeover.

Vice-President, G. R. HANKS.
Taylor Warton Iron & Steel Co.,
High Bridge, N. J.

Precautions to Take When Installing Ball or Roller Hanger Bearings

BALL and roller lineshaft bearings have established for themselves a permanent position in industry. The saving in power, less frequent lubrication, and cleanliness are points that should not be overlooked. Tests have shown in a number of instances that the saving in power will pay for the installation in a comparatively short time.

However, there is one factor in connection with the use of such bearings that is likely to cause trouble unless care is taken in the installation. This is the problem incidental to getting bearings of the solid ring type off the shaft when this becomes necessary. Practically always the bearings are put on "to stay," because it is thought that there will be no changes made in the shaft layout. However, all industrial operating men know that practically all

assemblies that are put up to stay have to be taken down at some time. For example, a new management decides upon a shifting of machines or a general repowering; or a shaft hanger breaks, a sleeve loosens enough on the shaft to score or to allow the shaft to pound, or a solid cast-iron pulley has to be taken off the shaft. Again, perhaps some accident has been severe enough to bend the length of shaft or to crack a bearing cone.

These are some of the things which experienced maintenance men know might happen. No one can forsee them, but if any one of them did happen, one or more bearings would have to be taken off the shaft. Frequently the discovery is then made that the bearing has rusted on the shaft during its period of service.

I have found that this factor enters regardless of whether cast-iron or steel sleeves are used in contact with the shaft, or in internal contact where the parts related do not move. In a number of cases the sleeve has been rusted so tightly that it could not be removed.

In such cases it is usually necessary either to shatter the ring members so they can be picked out in small pieces or to saw off the shaft close to the bearing in order that it may be forced out in a press. A job of this kind involves taking the shaft down, whereas this would not be necessary if certain precautions had been taken at the time of installation.

Before installing bearings it is customary to wipe off the shaft and bearings so that they will be clean and dry. This leaves oil or grease only on the balls or rollers, and so the parts are put together dry in what would seem to be the best possible condition for service.

In the course of a few years it will be found that these same dry parts have rusted badly, thus creating a strong bond between parts which are already mechanically tight. This difficulty seems to be independent of the so-called "improved" designs of clamping members; it must always be considered where iron or steel parts are in contact.

The majority of men have sweaty hands, not necessarily the wringing wet kind, but exuding an unnoticed dampness that will pave the way for corrosion due to atmospheric action. Given time, rust will as surely cover the spots that the men touch as it will the finished cast-iron surface that has been marked with common chalk. The rubbing of the hands over a shaft or inside a hole as the last act of cleaning off before assembly will be the cause of rust starting.

The only way to avoid this trouble is to oil or grease all surfaces of the several parts before they are put together. Rusting takes place at the points of contact that have no relative movements. This difficulty is serious enough to merit attention from all operating and maintenance men. In the days of plain bearings it was a simple job to replace the bearings if they became worn, but ball or roller bearings are of necessity more difficult to handle. The man who has not done any of this work would naturally think that the bearing would come off with about the same amount of labor as was employed in putting it on but actually it does not.

When the job of changing a bearing comes up, he gets a helper and starts to do it, thinking that he will get the job done in a few hours' overtime. However, he finds that rust has preceded him and he has to recruit his force to double the number of men and to work all night.

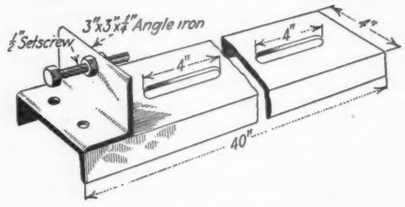
The new ball and roller hanger bearings have not been in use a sufficiently long time to require changing and so the difficulties of removal are not generally realized. In many cases, too, the men who have to take the shaft down do not have any idea what was the cause of this trouble, nor how to prevent it in the future.

DONALD A. HAMPSON.

Plant Superintendent,
Morgans & Wilcox Mfg. Co.,
Middletown, N. Y.

Use of Channel Iron in Making Sliding Base for Motor

IT BECAME necessary recently to make adjustable bases for some motors that had been installed on endless belt drives without provision to take up the slack. These bases were made as shown, and found to be entirely satisfactory.



A slot was cut in the channel iron for the leg bolts of the motor, whose position is adjusted by a setscrew.

Slots 4 in. in length were cut in 4-in. channel iron to take the motor leg bolts, and a piece of 3-in. x 3-in. x ¼-in. angle iron was fastened on one end. The angle iron was tapped for a ½-in. setscrew with locknuts to force the motor back so as to tighten the belt.

Two such slides were required for each motor. The length of the channel iron, however, varied according to the dimensions of the motors.

Denver, Colo. R. M. THOMAS.

Routine for Lubrication and Inspection of Cranes

IN ONE of the largest steel plants, where the crane inspector is not a member of the crane repair gang, a weekly detailed inspection is made, usually on Friday, of all parts of hot metal and ladle cranes, and elevators. As the inspector goes along, he makes notes of anything he finds which needs attention immediately or in the near future. He carries a hammer and a short bar with which he tests the tightness of bolts and caps and checks up the amount of play in the bearings. His inspection covers every electrical and mechanical part of the cranes.

The inspectors report is typewritten; one copy is made for file, one for the superintendent of the electrical department, one for the general foreman, and one for each section foreman. If the inspector finds that any part needs immediate repair, this is reported to the foreman in charge of the works at the place where the crane is located. This report which is made by word of mouth, is noted without delay on the inspection report. Cranes other than those mentioned above are inspected by the cranemen who, while oiling their cranes, report any trouble or irregularities to their foreman.

In addition to the reports on the hot metal, ladle and heavy roll cranes, a chain and cable report is made up and carried forward each month showing the date of the last change and the number of tons or days to run until the next change. The tonnage or time allowance, as the case may be, is determined by years of experience. The ropes or chains are removed regardless of their condition at the expiration of the period. The 1½-in. chains on old ladle cranes are minutely inspected, and if repairs are necessary, they are sent to the factory which produced them to have worn links replaced with new ones.

The entire chain is then annealed and proof-tested to the original strain, and a test certificate is sent back with the chain. The chain is then held in storage for another run. Smaller chains when removed are not again used on the cranes from which they were taken. The good ends of such chains are cut off and used for slings, and the worn-out parts are scrapped.

Wire ropes that are removed from hot metal and roll cranes are never again used on these cranes. The worn or defective portions are removed from the ends, and then they are used on yard cranes where shorter lengths are employed. Ropes and chains are inspected each week by the crane inspector and their conditions noted because it has been necessary in a few cases to remove ropes before the alloted tonnage or time had been reached.

These cases were due to defects in the ropes or because of their being burned. This periodic inspection, it is believed, has prevented sudden failure and possibly damage or serious tie-up.

Lubrication of cranes is handled by the crane operators, except in extremely heavy tonnage periods when there is an oiler for the strippers and pit furnace cranes. Some of the cranes are equipped with a force-feed, grease gun system, but most of them have hand-oiled bearings with some hand-screw feed grease cups. In some parts of the works where the crane service is continuous, the operating departments provide a stated period of 20 to 30 min. for lubricating the cranes. However, they are usually lubricated when the operator sees an opportunity, which may come any time during the day. When the time for oiling is not fixed, there is frequently trouble with operating foremen who do not like to have the cranes stopped for lubrication.

D. W. BLAKESLEE.

Pittsburgh, Pa.

In the Repair Shop

This section is devoted to repair work on electrical and mechanical equipment. Special attention is given to shop or bench tools and short cuts or improved methods of handling work of this character. Contributions are always welcome.

How to Reduce D.C. Voltage for Testing Purposes

OCCASIONALLY it is necessary to reduce the voltage of a direct-current circuit for testing purposes, and in the absence of other suitable means of doing this a water rheostat will be found very convenient. A rheostat of this type that will be satisfactory for most purposes may be made as follows:

An ordinary oil barrel can be used for holding the water, and one rectangular plate about 1 ft. wide and 2 ft. long can be supported by a cross member at the top of the barrel. The other plate should be arranged with a pulley and counterweight so that it can be raised or lowered at will. This plate should preferably have its lower end terminating in a point, the plate becoming wider toward its upper end. The upper end of this plate should be about the same width as the other plate. The movable plate should slide between guides made of pieces of 2x4-in. wood.

With the plates mounted about 6 in. apart and the water carefully salted, a very delicate resistance control can be obtained. It should be remembered, however, that the resistance of the solution varies greatly with its temperature, and if used continuously with too small a barrel, constant adjustment and watching of the plates may be required, although an ordinary 50-gal. barrel should be fairly satisfactory for most work.

In using this method of reducing d.c. voltage, it should be remembered that any contacts in the circuit actually have to break a 110-volt current, so that if a small motor or a bell is being operated, there may be burning at the contacts.

Fig. 1 of the accompanying illustration represents a means of reducing direct current that is in general a modified potentiometer method wherein two water rheostats are used. To operate this d.c. reducer, the short-circuiting switch *S* at box *B* is kept closed and the plates in box *A* are adjusted until the current flowing in the test circuit is slightly higher than the current desired. The adjustable plate in box *B* is then lowered until it just makes contact with the salt solution. While switch *S* is quickly opened and closed, the current and voltage in this circuit is noted. If the current is too high, it can be quickly lowered by adjusting box *A*, and then an adjustment in box *B* will give a finer and a closer adjustment. The advantage of this method lies in the fact that the voltage across the test circuit is only that across box *B*, so that any contact in the test circuit would break only a fraction of the line voltage in box *B*. It also allows a very easy and careful adjustment of the test line voltage, which is not possible with the single water rheostat previously described.

If it is desired to construct a permanent testing outfit, the method illustrated in Fig. 1 may be further modified by substituting either a fixed or a variable type of resistance for the water rheostat. For instance, assuming that the current desired is from 15 to 20 amp. at 15 to 20 volts, a method similar to that shown in Fig. 2 may be used. With 20 amp. in the test circuit and 1 amp. passing through resistance *B*, the total current taken from the 110-volt circuit would be 21 amp. Assuming the test circuit to require current at 20 volts, the minimum resistance in this circuit would be about 1 ohm at 20 amp., and 1.33 ohms at 15 amp. The resistance of *B* can be made 1 ohm with a capacity of 1 amp. and a fuse should be inserted in the circuit, as shown in Fig. 2, to limit the current to the set value. The resistance value of *A*, in order to allow 21 amp. to flow, must be the difference between the joint resistance of the test circuit and *B*.

Then the total resistance across the 110-volt circuit is 110 volts ÷ 21 amp. = 5.23 ohms, and the joint resistance of *B* and the test circuit with 20 amp. flowing would be 20 ÷ 21 = 0.95 ohm. The resistance of *A* would, therefore, have to be 5.23 — 0.95 = 4.28 ohms. With the test circuit disconnected and the 110-volt supply still connected, the current taken from the line would be 110 ÷ (4.28 + 20) = 4.53 amp. It may often be best to have a fixed resistance at *A* and *B* and then insert a variable resistance in the test circuit. The latter resistance need be only about 0.5 ohm with a current capacity of 20 amp. The fixed resistances can readily be purchased or made up of resistance wire of the Nichrome or Climax type, preferably, as their change in resistance due to temperature is not great.

A variable resistance of the slide-wire type can be made up by winding bare resistance wire around an iron pipe about 1 in. in diam. and insulated with mica or asbestos, keeping the turns of wire about ¼ in. apart. This arrangement allows very close adjustment of the voltage. Fixed resistances that are made up so that they can be screwed into a receptacle are available on the market. These may be arranged in series or multiple groups to give any desired range of fixed resistance for any low current values. The proper size of resistance wire for the current to be carried can be obtained from the manufacturer's catalog.

C. OTTO VON DANNENBERG.
Electrical Division,
General Engineering & Management Corp.,
New York, N. Y.

Two simple methods of reducing direct current voltage for testing purposes.

The diagram in Fig. 1 shows how a test circuit should be connected to two water rheostats that are connected in series. In Fig. 2, a variable resistance in the test circuit can be used in conjunction with two fixed resistances, *A* and *B*.

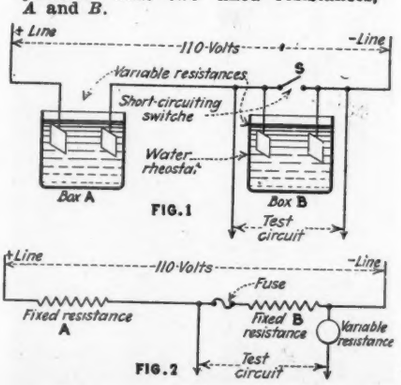


FIG. 1

FIG. 2

Unusual Behavior of Motor Due to Design

THE following experience caused much unnecessary trouble and discussion on an overtime job that required the rewinding of the stator and rotor of an induction motor.

The rotor coils were made of strap copper, three turns per coil, the copper being bent on edge. A complete group had been made at one time without cutting the copper, which reduced the number of soldered joints to a minimum, as there was only one starting and one finishing lead for each group.

After the rotor was stripped, the coils were removed carefully so as to keep them in shape. Then all the coils were retaped with one half-lapped layer of 0.007-in. cotton tape, not treated.

The rotor was rewound and connected and when the motor was assembled the brushes were lifted to open the rotor circuit. Current was applied to the stator winding to make a balance test, and while the stator winding was excited, the shaft of the rotor was turned slightly; to our surprise the rotor came up to speed. This would indicate that there was a shorted coil in the rotor, as an open-circuited rotor should not have any current induced in it, with a series-star connection.

We then removed the rotor and used the growler to try to locate the shorted coil, but the winding tested

clear. We next applied d.c. current, and with two needle points took a test similar to the bar-to-bar test used on d.c. armatures, by pushing the needle points through the insulation and testing across each three coil turns, but this test showed clear. So we next assembled the machine and gave it a 6-hr. full load run, checking the rotor winding at ½-hr. intervals for hot coils, but apart from a growling noise, the motor operated satisfactorily.

We had noticed that the rotor had very wide teeth, and it was our final conclusion that the width of the teeth was the cause of the trouble, as we judged that eddy currents of sufficient strength were set up in the teeth to produce enough torque to bring the rotor up to speed, if given a start.

This was proved later when the same customer sent in the spare motor, which was of the same make and type. We checked the serial number to ease our consciences.

When this machine was dismantled, we stripped the rotor and held it until the stator had been rewound. Then we put the bare rotor in the frame and applied current to the stator; when the rotor was given a start it soon came up to speed. The solution of this trouble was simple enough, but it had all parties involved guessing for a time.

A. C. ROE.

Renewal Parts Engineering Dept.,
Westinghouse Electric & Manufacturing Co.
East Pittsburgh, Pa.

Round Grooving Tool for Slot Wedges Saves Time

CUTTING the rounded grooves in slot wedges with a knife is a slow process and it is more difficult to get them even, so that the paper will be folded in the slots just as you want it. Some repair men grind the grooves in the wedges on an emery wheel, but this usually leaves a burr on the end.

Recently, I made a gouge, as I call it, out of an old 8-in. half-round file by grinding a groove in the end on the flat side at an angle of about 45 deg. Rounding out this groove to correspond to the curvature of the back and finishing it provided a cutting edge of about the correct proportion for all slot wedges.

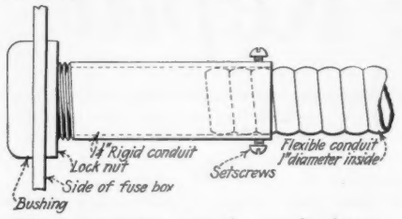
NICHOLAS J. WEISS.

West New York, N. J.

Method of Making End Connection for Flexible Conduit

WHEN the electricians at a plant in Michigan, which is located a long distance from any source of supplies, were called upon to connect a 1-in. flexible metal-sheathed conduit to fuse boxes it was found that there were no connectors in stock. Accordingly a few connectors were made up, similar to the one illustrated in the accompanying sketch. They were made as follows: After threading a 1¼-in. rigid conduit, a short piece was cut off with a hacksaw. Three holes for setscrews were drilled and tapped in this short piece near the end without the threads.

Preferably, these holes should be equally spaced around the conduit. On the threaded end of the connector were screwed a bushing and a locknut, and by tightening them up on opposite sides of one side of the fuse box the connector is held rigidly. After the flexible conduit was forced into the connector from the end containing the setscrews, the flexible conduit was securely fastened in the connector by tightening up the setscrews.



This connector can be made from material ordinarily kept in stock.

This connector was not hard to make and served us well in an emergency.

Electrician, CHAS. A. PETERSON.
Fairbanks Exploration Co.,
Fairbanks, Alaska.

Motor-Driven Grinder Pedestal Built by Arc Welding

THE welded steel grinder pedestal shown in the illustration was recently constructed in one of the departments of the Lincoln Electric Co., Cleveland, Ohio, and shows an interesting application of the arc welding process in reducing the cost of certain types of shop equipment. When the cost was calculated it was found that this pedestal and motor complete cost less than the old belt-driven grinder with cast-iron pedestal which it replaced.

The old grinder cost $114 to put it into operation, which includes $60 to cover that portion of the lineshaft and belt chargeable to it. The welded pedestal grinder shown cost $77.60 complete, which includes the cost of 70 lb. of steel, assembled and welded with overhead on labor cost at 200 per cent.

From an operating standpoint the advantage lies with the motor-driven grinder in that its operating cost for an 8-hr. day averages about 15 cents, or $45 a year. Figured on the same basis, the operating cost of the old grinder, driven from a lineshaft, was 24.6 cents a day, or $73.80 a year. On a 10-year basis the saving in operating cost would thus amount to $288.

This grinder pedestal was built of small steel shapes by arc welding.

Unusual Motor Trouble Cause of Production Loss

RECENTLY, I found that in the course of a month I was averaging two 30-amp. fuse renewals per day in the circuit of a Type KH, two-phase, 220-volt, 60-cycle, 3,400-r.p.m. Watson induction motor that was driving a P. B. Yates self-feed rip saw. The rotor was fitted on one end of the saw arbor while the stator frame was fastened to the arbor bearing casting.

In cleaning this motor I noticed where the rotor had at one time rubbed the stator core. Upon investigation I learned that the babbitt in the arbor bearings had worn and the mechanic in charge of taking up bearings had neglected to lower the stator of the motor accordingly. The rotor eventually reached the point of contact with the stator core, producing heat enough to char the wedges in the stator slots as well as the insulation of the coils. I noticed that some of the coils were bare, and upon testing with a lamp, this being the only available equipment, I was surprised to find no indication of a ground.

I reassembled the motor after cleaning and put it into service once more; this, however, did not eliminate the blowing of the fuses. I continued to give this motor a good deal of attention; so one day after I had replaced a fuse it came to my mind that I had read an article in INDUSTRIAL ENGINEER some months ago, treating on the surging of coils under load. I concluded that these damaged coils under the charred wedges were surging, or that the charred insulation was permitting miniature arcs to jump from one strand of the coil to the other, increasing the current in that phase.

On the basis of these conclusions, I decided to balance the cost of rewinding against fuse renewals and loss to production. It was estimated that the loss in labor production per week was $13.40, on the basis of two fuse renewals per day; the operator and his helper were idle for an average of 15 min. for every fuse renewal. I also estimated that $56 would cover the cost of rewinding this stator. When these facts were placed before the superintendent, permission was granted to proceed with the job of rewinding.

This solved the problem, for the motor is now rendering efficient service. In this case, the cost of labor, fuse renewals, and production lost on this machine in one month paid for rewinding it.

E. L. WAY.

Ada, Ohio.

New Equipment

for plant operation and maintenance

Industrial plant executives concerned with the selection and operation of mechanical and electrical equipment will be interested in these new devices which are designed to improve plant operation or reduce operating and maintenance costs.

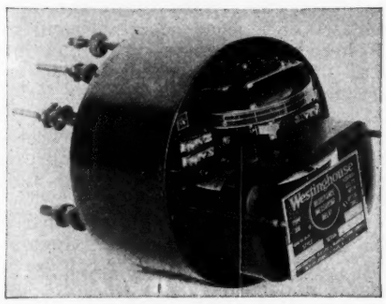
Resistance Measuring Relay

A NEW line of direct-current relays, filling an important place in this field, has been developed by the Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

This new X line, which includes resistance measuring, over-current voltage, polarized and relays of other types, closely resembles the Westinghouse induction-type alternating-current line of relays, and occupies about the same amount of switchboard space.

The new relays, which operate on the magnetic-vane principle, can, according to the manufacturer, have their operating values of current or voltage and their time of operation determined with a great degree of accuracy.

The resistance-measuring relay type XM has been developed for automatic service-restoring circuit-breakers and actually measures the resistance of the feeder.



Westinghouse Type XM Resistance Measuring Relay

A particular feature of the XM relay is its time limit, which prevents the breaker from pumping rapidly when the trouble is of a recurring nature. This new line of relays is particularly useful in automatic substations.

Tapered-Roller Bearings for Transmission Applications

COMPLETION of its line of power transmission equipment by the addition of a line of equipment provided with Timken roller bearings has been announced by the Medart Co., Potomac and De Kalb Streets, St. Louis, Mo. This addition consists of four units: A spherical ball-and-socket pillow block, a ball-and-socket hanger bearing of the dumb-bell or hourglass type for lineshafts, a unit mounting for incorporation into machines and special mountings or special equipment, and a loose pulley for lineshaft and countershaft usage, according to the manufacturer.

The general construction as described by the manufacturer is as follows:

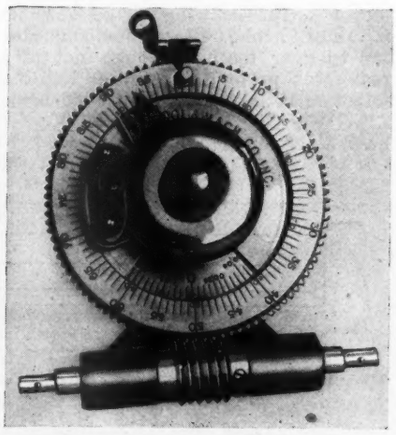
The Medart, Timken-equipped unit comprises two Timken tapered-roller bearings, assembled on a sleeve of ground steel tubing to form one unit and fitted into a finished cast-iron hub. This hub is machined to fit into a suitable housing adapted for use either in the spherical ball-and-socket pillow block, the unit mounting for building into duplicate machinery, or the loose pulley. The steel sleeve is slotted at each end and is held tight on the shaft by steel clamping collars.

Lubricant is forced into the races of the roller bearings through Alemite-Zerk fittings. Grease seals are placed in the flanges at the ends of the bearing to prevent dust from entering or lubricant leaking out. The large ends of the rolls point inward or toward the center of the bearing, which assures lubricant being pumped away from instead of toward the end inclosures, it is stated.

Revolution Stop Counter

MARKETING of a revolution stop counter involving several original design features has been announced by the Viking Tool & Machine Co., Inc., 745-759 Sixty-fifth St., Brooklyn, N. Y. This counter is for use in automatically stopping a machine after a predetermined number of revolutions, ranging from 1 to 9,750, have been made. The device is particularly applicable to various types of coil-winding machines where a fixed number of turns are to be wound, for linear measuring machines, power presses, screw machines where a limited production is required, chemical mixing machines, and textile and printing machinery.

Electric-Contact Type of Viking Revolution Counter With Automatic Stop.

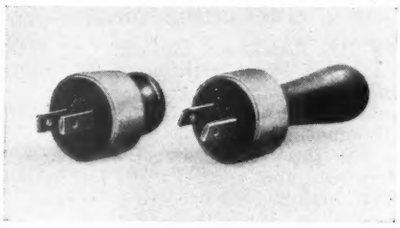


Three styles of counters are made, of which the electrical-contact type is illustrated. Stopping of a machine is accomplished by a make-and-break electrical contact that operates a suitable relay. A second type of counter is equipped with a mechanically operated plunger that operates the clutch for stopping the machine. The third style is a plain counter, by means of which the number of revolutions or strokes made by a machine can readily be determined by observation. This style of counter is limited to 9,900 revolutions; however, by means of suitable gearing between the device and the rotating member any reasonable number of revolutions above this can be counted.

The device consists essentially of a driving worm and a split wormwheel consisting of two disks. There are 100 wormwheel teeth on the periphery of the outside disk, and 99 teeth on the inside disk. The two disks are mounted on a single stud and for every 100 revolutions of the worm the rear disk advances one one-hundredth of a division over the front disk. This central stud also carries a lever for setting the predetermined number of revolutions, and for engaging a trip.

Handle Cap Plugs

MARKETING of two new designs of handle cap plugs has been announced by the Beaver Machine & Tool Co., Inc., 625-643 North Third St., Newark, N. J. These cap plugs, which differ only in the length of the handle and are shown in the illustration, are designed to replace the ordinary caps on small portable electrical equipment such as drills, gluepots, and so on.



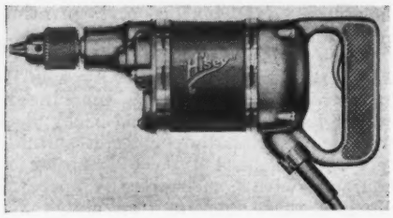
Beaver Handle Cap Plugs

The handle, which is hollow to receive the cord, is made of wood and the terminals are mounted on a molded composition base. This base is protected at the end by a nickel-plated ferrule, which also serves to hold the base and handle firmly together.

Standard-Duty ¼-In. Universal Drill

MARKETING of the new Hisey standard-duty Type 18-CU, ¼-in. universal electric drill, shown in the accompanying illustration, is announced by the Hisey-Wolf Machine Co., Cincinnati, Ohio.

Like other Hisey drills this unit is equipped with a standard electric motor of this company's design and manufacture which is said to be particularly



Hisey Type 18-CU, ¾-in. Universal Electric Drill

adapted for the service. The motor is mounted on ball bearings, which in turn are fitted in a way to eliminate slip and creeping action, it is stated. Also, the gear on the armature shaft is removable. All gears are made of high-grade steel, electrically heat-treated. The compound gear shaft is supported with a bearing at each end. The Jacobs chuck, which is standard equipment, is fitted to a hardened and ground, tapered spindle. The chuck spindle is automatically lubricated through the gear case.

Including other construction features brush-holders with adjustable spring tension are mounted as a separate unit on a Bakelite yoke to facilitate brush adjustment when necessary. The end handle cover is a rugged casting which carries the pressure applied and being independent of the motor and motor bearings relieves them of strain. The automatic, quick-release-type switch is mounted in the end grip handle.

Gas Cutting Torch

THE Alexander Milburn Co., 1416-1428 West Baltimore St., Baltimore, Md., has just placed on the market a gas cutting torch for use with illuminating and byproduct gases.

The torch is constructed of bronze forgings and specially drawn tubing. The high-pressure cutting oxygen is controlled by a thumb valve, which remains fixed in either the open or closed position. The arrangement of the gas tubes, it is claimed, gives great transverse strength to the torch, which is substantially built, well balanced and easy to handle. The torch is 21 in. in length and is supplied with a complete range of tips for light, medium and heavy cutting.

A bunsen burner, contained within the torch, burns illuminating gas. This superheater, which is an outstanding feature of the Milburn torch, heats and expands the cutting oxygen, as well as the preheating gases, raising the temperature of the cutting oxygen to approximately 100 deg. C. prior to combustion, thereby increasing the temperature of the gases at the torch tip and increasing the rate of flame propagation in the burning mixture.

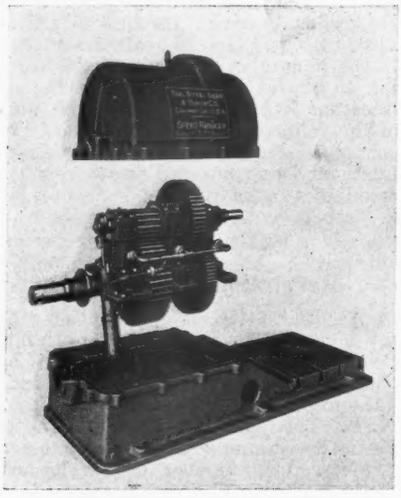
Speed Reducers

MARKETING of the Tool Steel speed reducers has been announced by the Tool Steel Gear & Pinion Co., Cincinnati, Ohio.

In the standard models plain spur gears with a 20-deg. stub tooth are used, although helical gears will be furnished, if desired, at slight extra cost. The gears are made of tool steel. All shafts are chrome-nickel steel, heat-treated and ground. Bronze bushings are used throughout, although ball or roller bearings can be supplied. These bushings are said to be of liberal design and are made of an alloy that is especially resistant to shocks and wear.

Forced lubrication to all bearings is supplied by a suction pump of simple design that is supported by the lower housing and driven by an eccentric on a slow-speed shaft. This pump, which contains no packings, springs or stem valves, will, it is claimed, handle oils ranging from the highest to the lowest viscosity. Particular care has been taken to prevent oil leaks, by a buffer joint in the lower housing and through the use of deflector rings and felt wipers in the packing boxes for the shafts.

The design of this reducer is said to be unusually rugged and compact, and particular attention has been given to accessibility for inspection or replacement of parts.



Tool Steel Speed Reducer

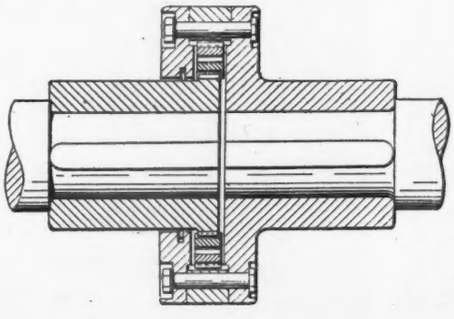
Flexible Shaft Coupling

DEVELOPMENT of the flexible coupling shown in the accompanying illustration has been announced by J. Y. Dahlstrand, Standard Turbine Corporation, Scio, N. Y. The coupling consists of two hubs keyed to the driving and driven shafts respectively, as shown in the drawing. One hub has externally hobbed claws somewhat similar to gear teeth, although not of a gear-tooth profile. The other hub has bolted to it an internally hobbed member of much larger diameter. In addition, there are one or more floating rings, one of which is split, with teeth on both the inside and outside circumferences that are interposed radially between the two hubs. The whole assembly is tightly closed and is lubricated by grease, injected through a connection in the side of the coupling.

The manufacturer makes the following statements concerning the coupling: It is made of steel throughout, so that it can be operated at high speed. It is free to move endwise to the extent of ¼ in. without imposing any thrust on either of the rotors. It is designed to permit a considerable degree of angular misalignment and to have torsional flexibility. The coupling will also take care of a certain amount of lateral misalignment, but will transmit any load imposed, even with a considerable misalignment.

Alignment of the coupling is checked by measurement with a gage furnished with it. The coupling can be disconnected to permit operation of the prime mover without running the driven machine, or vice versa, as with duplex drives, without completely dismantling it, it is stated.

Construction Details of Dahlstrand Flexible Coupling



Self-Cleaning Air Filter

ADAPTATION of the Midwest principle of air cleaning to the self-cleaning type of filter has been announced by Midwest Air Filters, Inc., Bradford, Pa. This clean air filter consists of a sheet metal housing inclosing the filter chain. The filter consists of demountable cells which are arranged in an endless chain. The manufacturer states that a positive air seal and air lock have been developed at all points of contact within the chain, as well as between the filter chain and the housing.

A sediment drawer is provided at the bottom of the tank to accumulate dirt; this sediment drawer can be removed and the dirt emptied when convenient. The filter can be bolted directly to a wall or partition. The filter chain is built on the impingement principle with a viscous substance used on the cells. Operation may be on a continuous or intermittent basis. The filter chain is driven by a ¼-hp. motor with a speed-reduction unit and a silent-chain connection.

The air flow is through both sides and the top of the filter and the direction of flow may be through the duct opening or vice versa. These filters

are supplied in standard units with rated capacities of 10,000 to 25,000 c.f.m. Units may be arranged in multiple to obtain any desired capacity within reason.

It is stated that no operating attention is required, because the dust settles in the Viscosine tank while the cell is passing through and a fresh surface of Viscosine is constantly maintained.

Wedge-Core Unit Heater

ANNOUNCEMENT is made of the marketing of the Herman-Nelson Unit Heater by the Herman-Nelson Corporation, Moline, Ill. A view of the assembled unit is shown in the accompanying illustration. A feature of this heater emphasized by the manufacturer is that it is built to withstand steam pressures up to 100 or 125 lb. and displaces heavy pipe coils, which have commonly been used on high-pressure work. A special feature is the aluminum radiating fins on the Univent steam radiator sections. This heater is especially designed for heating factories, warehouses, garages and other industrial buildings.

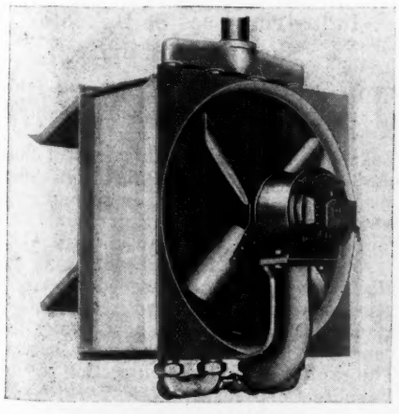
The Model 20 heater, shown here, weighs approximately 170 lb. complete with motor and louvre deflector and occupies 4 cu.ft. of overhead space. When the motor is operating at 1,150 r.p.m., it is stated that the fan on each unit will deliver in excess of 2,000 cu.ft. per min. and that at 850 r.p.m. it will deliver in excess of 1,200 cu.ft. of air per min.

It is stated also that it will operate at any steam pressure from atmospheric to 125 lb. When operating at 1,150 r.p.m., with inlet air at 50 deg. and steam pressure at 5 lb., it will deliver the equivalent of 560 sq.ft. of radiation. The same unit with inlet air at 50 deg. and with 100 lb. working steam pressure will deliver the equivalent of 960 sq.ft. of radiation.

Each unit may be automatically or manually controlled without reference to any other unit.

The radiator is of the extended surface type, but differs in that the core or steam way in it is cast in one piece of a special alloy and the aluminum fins are wedged on the one-piece cast core and held in a metal-to-metal contact by spring action. Likelihood of leakage is thus eliminated, according to the manufacturer.

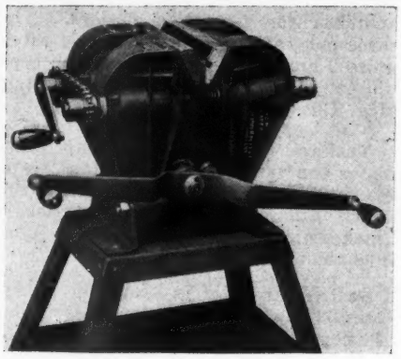
Herman-Nelson Model 20 Unit Heater



Belt Lacer

ANNOUNCEMENT has been made by the Clipper Belt Lacer Co., Grand Rapids, Mich., of the development of its new Clipper Speed Lacer, which is shown in the accompanying illustration.

This new lacer has been designed to handle belts up to 8 in. in width. It is claimed that by the use of an entirely new principle of operation, a three-quarter turn of the crank serves to apply a pressure of 45,900 lb. to the belt, embedding the hooks in perfect alignment and flush with the surface, so that wear on the pulleys is reduced to the minimum and the life of the joint prolonged. It is stated that the smallest belt may be laced by means of this tool with increased speed and economy.



New Clipper Speed Lacer

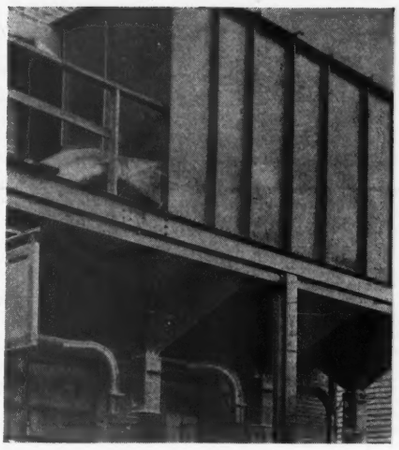
Cloth Screen Dust Collecter

NEW features have recently been incorporated in all Norblo dust-collecting equipment manufactured by the Northern Blower Co., Cleveland, Ohio.

The cloth screens in these dust collectors not only are stretched on wooden frames and heavily reinforced across the filtering area by steel braces and wires, but are stacked closely together; and the air, after the heavier suspended particles have been released by impact upon the baffle plates in front of the dusty air inlet, passes between the screens, through the fabric, and thence to the clean air chamber at the top.

The air baffle plates extend along the entire length of the dusty air chamber, and the dividing compartment that separates the clean air from the dusty air chamber has a walk-way or platform on its upper surface, which greatly facilitates inspection and maintenance of the screen.

To insure a thoroughly air-tight joint along the edge of the cloth, the wooden frame is provided with a deep groove into which the cloth is forced, and a superimposed layer of heavy cord and a series of nails at close intervals hold the cord and the cloth securely in position. All air leakage between the separate screens themselves is prevented by intervening wooden spacing strips alternately grooved and tongued, and packed with cloth on both sides. Moreover, air vents are made on both sides of each screen to provide ample air volume so as to keep the air-velocity at a minimum.



Norblo Cloth Screen Type Dust Arrester

New Locking Cord Connector

THE new Hubbell cord-grip locking connector with a rated capacity of 110 amp., 250 volts, has recently been announced by Harvey Hubbell, Inc., Bridgeport, Conn.

After plugging the cap into the connector, a slight turn is said to be all that is necessary to lock the two parts securely together.

The locking feature of this connector provides an extra and, it is claimed, very effective safeguard against accidental disconnection. This is of distinct advantage in industrial plants and other places, particularly where the service is unusually severe or where connectors are subjected to considerable vibration. These connectors are built for hard service, the bodies being made of a strong, black composition, while the caps are completely armored by a heavy, shield of steel which is heavily galvanized to prevent it from corroding.

Welding Lens

HIGH-GRADE welding lenses with special properties are being manufactured and distributed by Strauss & Buegeleisen, 30 Front St., Brooklyn, N. Y., under the name of Immunite. According to the manufacturers, the special properties of the lenses are: that they are absolutely optically ground and polished to exact plano and are claimed to be the best filter for injurious light rays yet devised. It is stated that this lens meets the requirements of the U. S. Navy specifications, and that it can be ordered and specified by shade numbers.

Each piece of Immunite will bear a certificate, giving its absorption of ultra-violet and infra-red rays, with the amount of visible and total energy transmitted.

Trade Literature

you should know about

Copies of literature which is described on this page can be obtained by writing to the manufacturer whose name and address are mentioned. It is always advisable to state the name and number of bulletin or catalog desired, as given in these columns.

Commutator Repair Equipment.—Catalog No. 7 describes the commutator slotting and grinding equipment and other motor repair accessories manufactured by this company.—Martindale Electric Co., P. O. Box 2660, Cleveland, Ohio.

Circuit Breakers—A 12-page circular, No. 1771, illustrates the construction, operation and application of the Types D-16, D-20 and D-26 circuit breakers.—The Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Maintenance—The advantages of periodic inspection of electrical equipment are set forth in a folder entitled "What Is Maintenance?"—The Maintenance Co., 449-53 W. 42 St., New York City.

Endless Belts—The proper way to make a splice or lap in an endless belt is minutely described and illustrated in a 16-page booklet.—Charles A. Schieren Co., 37 Ferry St., New York, N. Y.

Roller-Bearing Trolleys—A folder describes the Morris roller-bearing trolleys with illustrations of the construction and application and contains a list of sizes and capacities.—Herbert Morris, Inc., Buffalo, N. Y.

Portable Elevators—Bulletin 908 describes the H.S.G. hoist together with various types of loading platforms and elevators.—Revolvator Co., 336-352 Garfield Ave., Jersey City, N. J.

Ventilating and Exhaust Fans—A series of bulletins covers the ventilating and exhaust fans and fractional horsepower motors manufactured by this company.—The Emerson Electric Mfg. Co., St. Louis, Mo.

Motor-Generator Sets—Bulletin 145 includes descriptions and illustrations of various types of motor-generator sets, with tables containing various data on them.—The Robbins & Myers Co., Springfield, Ohio.

Panelboards and Cabinets—Folder 4737 describes the J. T. and N. J. T. safety type panelboards and cabinets. It also contains a table of the ratings and capacities according to box dimensions.—The Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Small Motors—A number of special designs of fractional horsepower motors are described and illustrated in Bulletin 1126.—Janette Manufacturing Co., 556-558 W. Monroe St., Chicago, Ill.

Wire Conveyor Belts—A booklet describes and lists the various sizes of flexible woven wire conveyor belts for handling material that must be annealed, sprayed, filtered, screened, dried, moistened, cooled, steamed, or otherwise treated simultaneously with its movement on the conveyor.—Conveyor Sales Co., 1085 Broad St., Newark, N. J.

Tumbler Switches—A circular describes two new Trumbull tumbler switches for use with motors. The three-pole, surface-type switch is rated up to 2 hp., and the two-pole, flush type up to ¾ hp.—The Trumbull Electric Mfg. Co., Plainville, Conn.

Trailers—An 8-page circular illustrates the various types of Clark trailers for industrial haulage and also the Clark hitch or automatic coupler.—Clark Tructractor Co., 1102 Days Ave., Buchanan, Mich.

Switchboard Meters—Bulletin 73 devotes 32 pages to a complete description of the construction as well as special features of the Sangamo alternating- and direct-current switchboard meters.—Sangamo Electric Co., Springfield, Ill.

Oil and Grease Equipment—A collection of bulletins illustrates and describes the Bennett oil and grease storage and handling equipment.—Bennett Pump Corp., Muskegon, Mich.

Preheating Torch—A circular describes Smith's preheating torches for use in connection with welding, for heating and bending metal, expanding parts, melting babbitt, drying molds, and crucibles, and similar work.—Smith Welding Equipment Corp., Minneapolis, Minn.

Dust Filter—Bulletin 181 shows with photographs and drawings the design and construction of the Whiting dust filter.—Whiting Corp., Harvey, Ill.

Babbitt—A small illustrated pamphlet entitled "Babbitt Metal Data" discusses the selection of babbitt metal and gives points to be considered in the use of babbitt for bearings, with instructions for casting the babbitt and fitting the bearings. A description of the grades of babbitts made by this company is also included.—Hoyt Metal Co., St. Louis, Mo.

Ventilating Fans—Catalog 1302 contains a list of specifications and prices on the complete line of fans manufactured by this company.—Robbins & Myers Co., Springfield, Ohio.

Welding Rod—A booklet entitled "A New Viewpoint on Metallic Arc Welding Parts" discusses the advantages of using a high-grade welding rod or wire as compared with a low-grade material by comparing the cost of the operator's time per pound of weld deposited.—Chicago Steel & Wire Co., 103d St. and Torrence Ave., Chicago, Ill.

Mechanical Brake—Bulletin 102-A describes the Clark type Three C brake for mechanical operation, such as in connection with the bridge drive of electric cranes.—The Clark Controller Co., Cleveland, Ohio.

Lift Trucks—The new model H Revolvator Liftrucks are described and illustrated in Bulletin 90-J. A table giving the dimensions of the various sizes of trucks is included.—Revolvator Co., 336-352 Garfield Ave., Jersey City, N. J.

Variable Speed Reducer—Bulletin 66 describes and illustrates a new type of speed reducer that is adapted for applications where a variation in speed is necessary. Variation in speed is obtained by manipulating a dial.—William E. Simpson, 100 Morgan Bldg., Detroit, Mich.

Gas-Welding Apparatus—Catalog 172-E describes and illustrates various types of welding and cutting apparatus.—The Alexander Milburn Co., 1416-1428 West Baltimore St., Baltimore, Md.

Architects' Specifications—A booklet covering almost any passenger or freight elevator installation is included in Warner's List of Architects' General Specifications.—The Warner Elevator Mfg. Co., Cincinnati, Ohio.

Lubricating Outfit—A number of circulars describe the G & B circular and rectangular tanks for storing and measuring lubricating oils.—Gilbert & Barker Manufacturing Co., Springfield, Mass.

Steel Melting Furnaces—Steel melting with Ajax-Northrup high frequency furnaces is described and illustrated in a leaflet.—Ajax Electrothermic Corp., Trenton, N. J.

Ball Bearings—A leaflet discusses a number of applications of ball bearings. Tables are included, that will assist in selecting and ordering the proper size of bearing.—The Transmission Ball Bearing Co., Inc., 1050 Military Road, Buffalo, N. Y.

Industrial Uses of Bakelite Shown in Exhibit

THERE is at present on tour in the central states a traveling exhibit showing the many and varied uses of Bakelite in industry. Upwards of 200 manufacturers who use Bakelite in their products are represented in the exhibit, which will cover important industrial centers in Ohio, Michigan and Indiana.

As the caravan reaches each stopping place, invitations are issued to engineers, manufacturers, and to the public at large to visit the show, which is usually held in one of the large hotels. The exhibit is under the direction of the Bakelite Corporation, New York, N. Y.